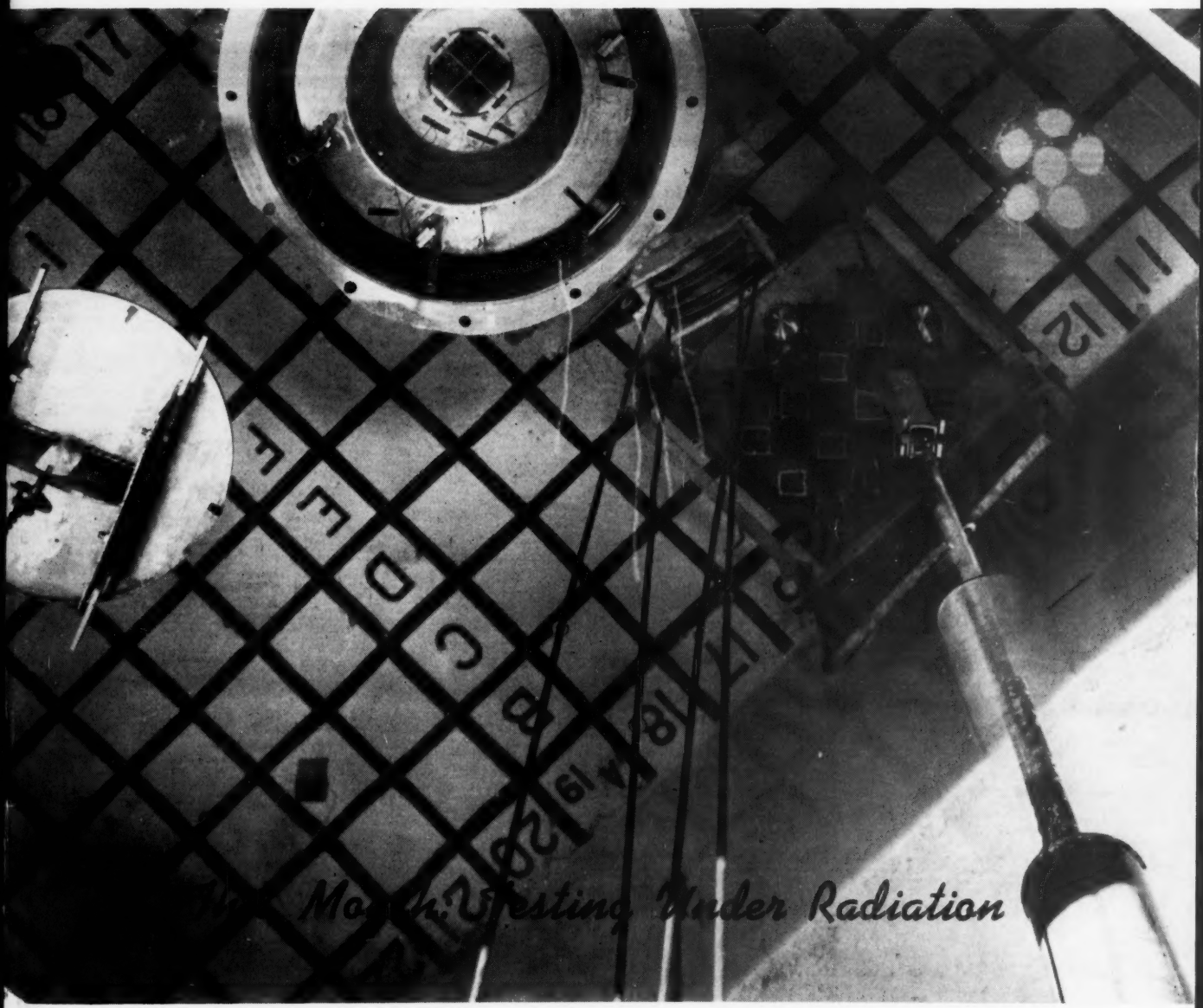
July, 1957

LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE



JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS

Five small Farval systems protect world's largest adjustable-rail milling machine

FARVAL—
Studies in Centralized Lubrication
No. 199

KEYS TO ADEQUATE LUBRICATION—
Trailer truck and car illustrate the tremendous size of this great machine tool. Red key-arrows indicate two of five Farval systems. Whenever you see this sign of Farval you know a machine is being properly lubricated. Farval manually operated and automatic systems protect millions of industrial bearings.

THIS 615-ton milling machine, installed at Schenectady, machines steam-turbine-generator parts up to 18 feet wide and 16½ feet high to close tolerances.

Vital to its smooth operation are five manual Farval systems which lubricate the rail nuts on the cross rail. Two of them are visible in the photograph. With Farval, accurately measured amounts of oil or grease can be delivered to bearings whenever needed.

Five small Farval systems are an insignificant part of the cost of protecting the $1.5-million investment in this world's largest milling machine.

You, too, can protect your machines inexpensively with Farval. Why not investigate, then invest! Just ask for Bulletin 26-S. Our representative will call at your convenience. The Farval Corporation, 3267 East 80th Street, Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.

LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE

Volume 13, No. 7

July, 1957

Staff

R. K. Gould, Editor
The Texas Co.
P. O. Box 509
Beacon, N. Y.

R. D. McCormick, Managing Editor
ASLE National Office

J. Sneller, News Editor
ASLE National Office

V. Blake, Editorial Assistant
ASLE National Office

A. F. Brewer, Consulting Editor
c/o ASLE National Office

C. L. Willey, Business Manager
ASLE National Office

Editorial Review Committee

R. K. Gould, Chairman
S. K. Talley, Shell Development Co.
A. C. West, California Research Corp.
H. S. McCulloch, Jr., Shell Oil Co.

ASLE Publications Board

D. W. Sawyer, ALCOA Research Laboratories, Chairman
R. K. Gould
R. D. McCormick
C. L. Willey

Publishers Representatives

Eastern and Central Regions

ASLE
84 E. Randolph Street
Chicago 1, Illinois

Western Region (15 states)
McDonald-Thompson

San Francisco 5, Calif.
625 Market Street
YUkon 6-0647

Los Angeles 5, Calif.
3727 W. Sixth Street
DUnkirk 7-5391

Seattle 4, Washington
1008 Western Avenue
ELliot 3766

Denver 2, Colorado
Colorado Nat'l Bank Bldg.
KEstone 4-4669

Houston 6, Texas
3217 Montrose Blvd.
JA 9-6711

Tulsa 4, Oklahoma
2010 South Utica
RIverside 3-1981

Contents

APPLIED SCIENCE

Dynamic Tests Spark Nuclear Lube Program 380

Planned Lubrication for 3 Plant Types
by R. W. Clark 384

RESEARCH, DESIGN, AND DEVELOPMENT

Some Effects of Gamma Radiation on Commercial Lubricants
by J. G. Carroll and S. R. Calish, Jr. 388

Thermal Conductivity of Aircraft Engine Lubricants at Low Temperatures
by V. E. Schrock and E. S. Sparkman 393

Transition Temperature for Surface Damage in Sliding Metallic Contact
by L. F. Coffin, Jr. 399

Industrial Dermatosis: Questions and Answers 406

CURRENT NEWS

Lubrication in the News 374

Personals 416

News Notebook 416

FEATURES

Asperities 379

Lube Lines 387

The Sight Glass 370

LITERATURE SUMMARIZED

Lubrication Abstracts
Compiled by the ASLE Abstracts Sub-Committee 418

Patent Abstracts
Compiled by Ann Burchick 420

TRADE INFORMATION

Advertisers' Index 420

New Products 372

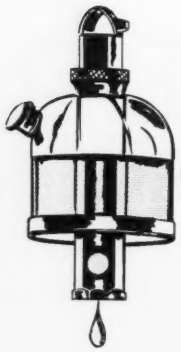
Cover Picture: Argonne National Laboratory High-Level Gamma Irradiation Facility No. 108-1336. View of pool looking down showing element rack with fuel element in place and fuel carrier with lid removed. (Courtesy Argonne National Laboratories.)

LUBRICATION ENGINEERING is published monthly by the American Society of Lubrication Engineers, 84 E. Randolph St., Chicago 1, Illinois. Current volume single copies 75c. Copies of issues from previous volumes $1.00, if available; Copies to Foreign addresses add 50c per copy. Annual Subscription $6.00 in the USA and Canada, $7.00 to all other countries.

Copyright 1957 by the American Society of Lubrication Engineers. ASLE will not be responsible for statements or opinions presented at its meetings or printed in its publications.

Second class mail privileges authorized at Chicago, Ill.

The Sight Glass



Highlights of Articles Scheduled for Coming Issues!

Journal Box Lubrication

A serious problem occurs whenever the normal heat dissipated in a journal bearing exceeds the amount of heat generated as a result of fluid friction from the viscosity of the lubricant in the clearance space between the bearing and the journal or the friction generated by the feeding wick and the journal. The "hot boxes" which result when this heat balance is distorted are actually a lubricant failure, since the function of the lubricant is to dissipate heat. In a case history of the effects of controlled lubrication engineering one railroad was able to show almost 300% improvement over the general industry results.

Some Practical Hints on Oil Circulating Systems

The essential elements required for efficient operation of circulating oil systems are described. Installation hints and components used with a typical system include pump capacities, storage tanks, heating coils, instrumentation, filters, pressure tanks and regulators. An operating and maintenance check list is included.

Filtration of Railroad Diesel Engine Lubricating Oils

Successful operation of diesel engines in railroad service is often dependent upon close control of the filter elements involved in oil filter maintenance. Inspection of the used filter element is valuable in estimating the general performance level of the filter. The size and shape of the locomotive unit as well as the diesel engine operating conditions dictate the type of oil filtration system to be used. The system is adequate so long as the construction and materials used in the filter elements are satisfactory and the filter change frequency is controlled. Substantial savings result from improved engine performance when alert control of oil filtration is employed.

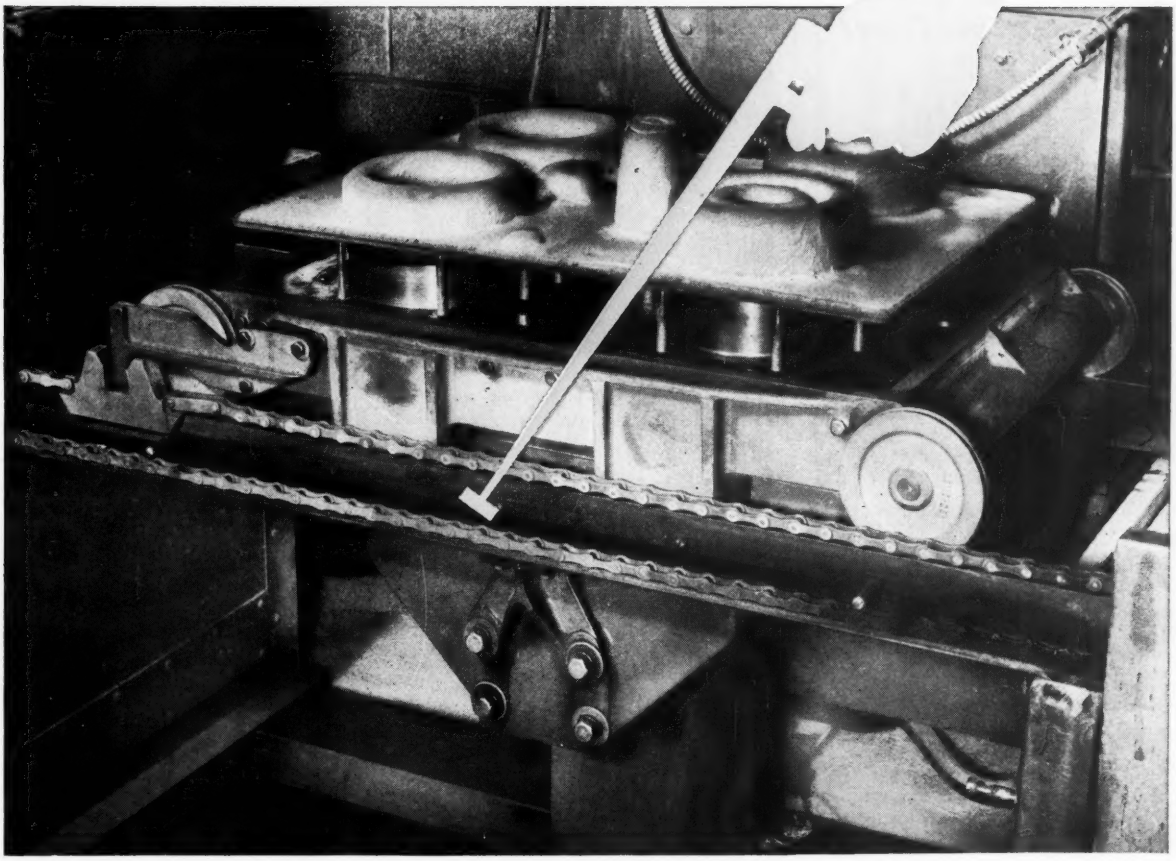
Synthetic Ester Lubricants

Synthetic esters have properties that make them good lubricants under conditions too severe for mineral oils. Early research in Germany led to commercial production, a good part from polyhydric alcohols and monobasic acids. Development in Britain and the USA concentrated on esters derived from monobasic alcohols and dibasic acids. The esters described in the paper improve the lubricity of silicone oils as well as mineral oils.

Numerical Solution of Reynolds' Equation for Sector Thrust Bearings

A method of solving the Reynolds' equation using digital computer techniques has been developed to predict sector bearing performance. The results compare favorably with experiment and known analytical solutions. The investigation indicates that good design criteria may be established for sector thrust bearings with arbitrary geometries, and possibly very accurate predictions may be obtained if the Reynolds' and energy equations can be solved simultaneously by this technique.

A Touch here does so much



TORRID TRAVELERS

A touch of 'Oildag',® and shell mold pattern carriages keep shuttling smoothly at temperatures of 400°F to 900°F, every 30 seconds, 24 hours a day. Wheels turn freely, hitches drop snugly into place, and chains keep driving; shell molding machines deliver at maximum capacity without interruption.

'Oildag' and other colloidal graphite dispersions are widely used on conveyor systems for glass annealing and for paint and enamel baking ovens where things must keep moving despite high temperatures and hard, continuous service.

In the kilns where porcelain products are fired, temperatures are even higher. Ordinary lubricants burn up, but 'dag'® dispersions keep kiln car wheels turning.

Wherever mechanisms must operate in high temperatures, and ordinary lubricants can't take it, chances are good that one of the many 'dag' dispersions will solve the problem. Talk with your Acheson Service Engineer soon, and write for Bulletin 423 — High Temperature Lubrication. Address Dept. LE-7.

dag®

ACHESON COLLOIDS COMPANY

Port Huron, Michigan...also Acheson Colloids Ltd., London, England

ACHESON COLLOIDAL DISPERSIONS:
Graphite · Molybdenum Disulfide · Zinc Oxide · Mica and other solids

Offices In: Boston · Chicago · Cleveland · Dayton · Detroit · Los Angeles
Milwaukee · Philadelphia · New York · Pittsburgh · Rochester · St. Louis · Toronto

Advance Information!

4th Joint Lubrication Conference

Co-Sponsored by ASLE-ASME

Papers currently being considered by the reviewing committee—

"The Effect of Aircraft Gas Turbine Oils on Roller Bearing Fatigue Life"

"Extremely Thin Film Hydrodynamic Lubrication"

"A Solution for the Finite Journal Bearing & Its Application to Analysis and Design — III"

"A Theory of Cutting Tool Wear & Cutting Oil Action"

"Solid Film Lubricants at High Temperatures"

"Investigation of Factors Governing Rolling Contact Fatigue Life in the NACA Fatigue Rig"

"Wear of Cobalt-Base & Stainless Steel Materials in High-Purity Water"

"Influence of Lubricants on Gear Fatigue"

"A Study of Piston Ring Face & Side Wear Characteristics by the Radioactive Technique"

"A Study of the Effect of Wear Particles & Adhesive Wear at High Contact Pressures"

"Lubricity Studies Under Extreme-Temperature Conditions"

"The Role of Atmospheric Oxidation in High Speed Sliding Phenomena"

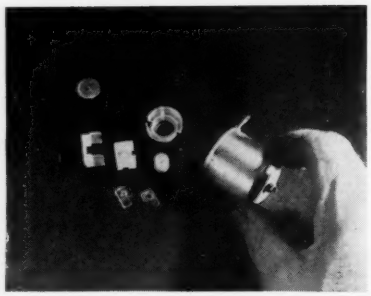
Watch *Lubrication Engineering* for further information on this important conference.

4th Joint Conference of the ASLE-ASME
October 7, 8, & 9, 1957

Royal York Hotel
Toronto, Ontario, Canada

New Products

NYLON LUBRICATES MOTORS



Miniature motors for use in the radio, electronics, phonograph instrument and automotive industries have been equipped with Plaskon nylon for insulation, self-lubrication, and durability. The nylon powder molds the lead insulators, motor brush supports, commutator hubs and governor mounting base. Moldability of small parts is also said to be achieved at relatively low cost.

Six series (100 to 600) of small DC motors are produced with torque ranges from .3 to 3½"-oz. and speeds varying from 1800 to 18,000 rpm for use with 3 to 24 volts. The 500 and 600 series motors are available with governors for constant speed applications.

NEW MOLD RELEASE SPRAYS ON

A mold release or parting agent for use in the production of plastic and rubber-molded products is now being marketed. The new product consists of a solution of low-molecular weight polyethylene in a mixed solvent system and is supplied in spray form.

The new mold release works through a film formed when hot or cold mold cavities or other objects are sprayed. This film provides release with a minimum number of spray applications, reportedly resulting in faster cycle time and reduction of rejects. Effective results are said to have been obtained with thermosetting plastic and vulcanized compounds as well as with casting or potting of epoxy, phenolic, furane and polyester resins. Barrett Division, Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y. will provide additional information on "Poly-Lease 77."

RHEOPECTIC GREASE

A new lithium grease bearing the brand name of RYKON R, is being marketed by Standard Oil of Indiana. The product is fluid in the original state and converts to a grease when subjected to a shearing action.

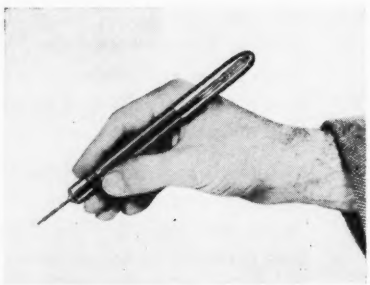
RYKON Grease R was developed by the Standard Research Laboratories as a lubricant for centralized systems. Such systems are currently in use in industrial machine lubrication, passenger cars, buses, trucks and farm machinery. The new automatic centralized lubricators require lubricants which are fluid because the pump used with the system is fed from a reservoir by gravity flow. The new product is ideally suited to such systems and feeds readily to the pump, and on application, is irreversibly converted to a grease.

Handling problems have been diminished with this material which handles like an oil but functions in the bearing as a grease.

The product has high lubrication value, oxidation and mechanical stability, heat and water resistance.

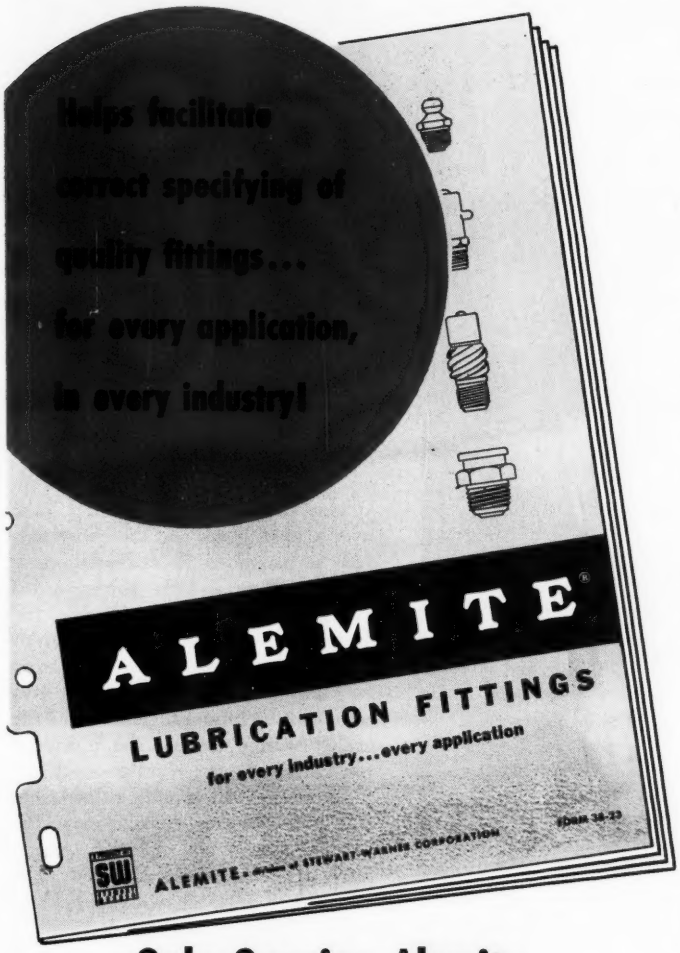
It is recommended for applications where the original fluidity offers an advantage in handling and dispensing and where the final soft consistency is satisfactory for lubrication.

OILER HAS PIN-POINT CONTROL

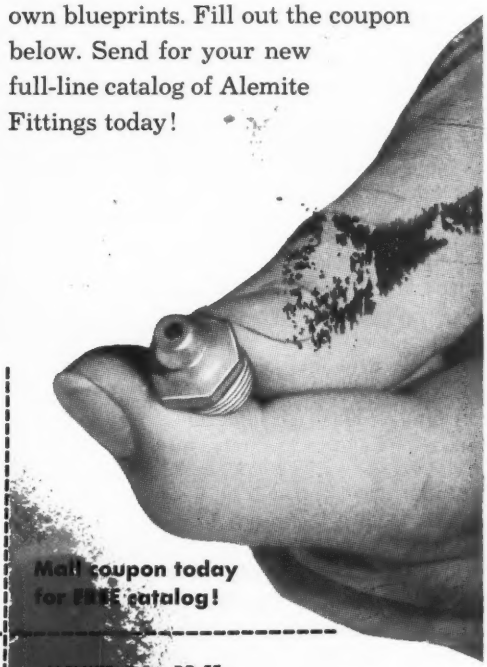


A new oiler is designed like a fountain pen to deliver exact amounts in both hole and surface applications. The oiler's spring-controlled steel point is pressed against the spot to be oiled. A drop is ejected and, if more oil is required, repeated pressing will deliver the exact amount. Additional information may be obtained from Dill Mfg. Co., 700 E. 82nd St., Cleveland, Ohio.

FREE! New Full-Line Catalog of
ALEMITE Lubrication Fittings!


Helps facilitate correct specifying of quality fittings... for every application, in every industry!
ALEMITE
LUBRICATION FITTINGS
for every industry...every application
ALEMITE, division of STEWART-WARNER CORPORATION
SW WARNER

Here is Alemite's new free catalog of the most *complete* line of fittings on the market! A simple, handy guide to fast, easy selection of the right fitting for every requirement. Contains detailed drawings of all Alemite fittings including the famous Alemite "Red-Ball" Hydraulic Fittings. Also lists many types of fittings that have been developed for special purposes—including relief fittings, measuring fittings and drive fittings. Complete with individual dimensions—ready for transfer to your own blueprints. Fill out the coupon below. Send for your new full-line catalog of Alemite Fittings today!



Only Genuine Alemite Red-Ball Fittings Offer These Four EXTRA Advantages!

1. Flat top with clean, dirt-cutting edge bites through dirt and old grease instantly!
2. Made *armor-hard* to resist nicks, scratches, distortion!
3. Tip has rounded contour to give extra working angle. No ridges . . . coupler won't slip off in tight quarters!
4. Extra-thick wall gives unequalled strength—withstands hard field service!

STEWART SW WARNER **ALEMITE** REG. U. S. PAT. OFF.

Division of STEWART-WARNER CORPORATION

Mail coupon today for FREE catalog!

ALEMITE, Dept. DD-77
1850 Diversey Parkway, Chicago 14, Illinois

Please send me your new, complete catalog of Alemite Lubrication Fittings—*free* of cost or obligation.

Name .....

Address .....

City ..... Zone ..... State .....

LUBRICATION IN THE NEWS

Colloidal Graphite Plays Important Role In Manufacture of Earth Satellite

A new "moon" expected to attain a speed of 18,000 miles per hour will be seen in the sky sometime this year about ten minutes after a three-stage rocket is launched at Patrick Air Force Base, on the East Florida coast. This moon, or earth satellite, is now being constructed under the supervision of "Project Vanguard" scientists as part of the United States' participation in the International Geophysical Year. When completed and launched, it will be a highly-polished magnesium sphere, measuring 20 inches in diameter and weighing 21½ pounds, including the delicate electrical and electronic instruments inside.

Earth Satellite Preparation—The shell is spun down to a hemisphere and colloidal graphite is applied to facilitate removal of the hemisphere from the block.

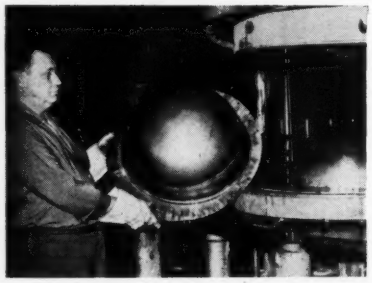
Colloidal graphite dispersions play an important role in the production of what will be the first of man's space-conquering vehicles. A dispersion of colloidal graphite in lactol spirits manufactured by Acheson Colloids Company, Port Huron, Michigan, was used as a lubricant and parting agent on the magnesium during deep-drawing and spinning.

In the fabrication of the shells a 32″ diameter sheet blank of AZ31B magnesium alloy 0.091 inches thick is sprayed with graphite. After the naphtha carrier has evaporated and left a tough, thin graphite film on the magnesium, the sheet is preheated to a temperature of 600-650°F. The pre-lubricated hot sheet is then inserted into a 750-ton hydraulic press and deep-drawn into a hemispheric shape.

Because of the extreme thinness of the sheet and the great heat and severe pressure to which it is subjected, it is necessary to prevent cracks, breaks and other defects from appearing in the material. Brooks and Perkins found that the lubricant used completely prevented galling and scoring of the drawn part and also eliminated metal pick-up on the die surfaces. In addition, there was no burn-off or loss of the graphite lubricant.

After being drawn, the shell is ready to be hot-spun to an exact hemisphere. Spinning is done on a lathe with the shell torch-heated to a temperature of 600-650°F.

To form the magnesium shell to the desired shape, the inside surface of the magnesium is first sprayed with colloidal graphite, after which the metal hemisphere is placed on a cast iron spin block held in the chuck of the lathe. The block is also coated with the lubricant. Thus the shell can be removed without damage to its inner surface. As the shell spins on the lathe a wooden tool is brought to bear on the shell surface. The pressure of the tool causes the hemisphere to take the shape of the spin block.



Circular magnesium sheet blanks being sprayed before preheating and drawing.

After the hemisphere has been spun to shape, a spun magnesium band with a depressed area is welded inside the shell, thus providing a sealed hollow interior area which can be pressurized. The welded hemisphere is put on a machining lathe over a form block and the entire surface is machined to extremely close tolerances to a skin thickness of 0.028″. Graphite is applied to the form block to facilitate removal of the hemisphere after machining.

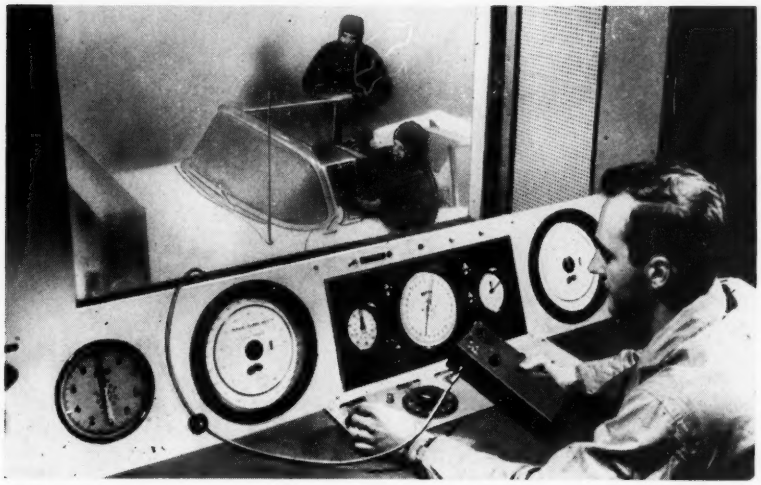
Two such true hemispheric sections will be joined together after the sealed section around the inside of the satellite has been pressurized and instruments which will record and transmit data on cosmic rays, the earth's magnetism, weather conditions, etc., have been installed. The pressurized sections will be held at known pressures and are designed to yield information as to the size and force of impact of micrometeorites which may strike the satellite.

New Dispersion Alloys At Armour Research

Small, hard particles a few millionths of an inch in diameter are being "dispersed" in alloys to form new high strength materials that will hold up at red hot temperatures. Armour Research Foundation metallurgists say the powder particles act like gravel reinforcement in an asphalt road. "Dispersion strengthening", Armour scientists say, also could increase resistance to abrasive wear.

LUBRICATION IN THE NEWS

New Dimensions in Petroleum Research Seen at Gulf Lab Dedication



Gulf Cold Room—Protected by heavy arctic clothing in —70 degree temperature, technicians check on how experimental gasolines, oils, greases and tires would stand up under use in sub-arctic environment.

Three new major buildings were officially dedicated at the Harmaville, Pa. Research Center on May 29, marking Gulf Oil Company's expansion of the 53 acre site into wider areas of instrumentation and research. Heart of the million-dollar laboratory complex is equipment designed to speed research projects in atomics, lubrication, and creation of new products by means of nuclear energy.

A 3,000,000 volt atom smasher, known as a Van de Graff particle accelerator, is the principal component of nuclear equipment, said to be the most versatile element of its kind currently in use by private industry. Although nuclear research has been used at Gulf for some years, company spokesmen stated that the augmented facilities will make possible an expansion of the work to every phase of lubrication and petroleum operations.

The new facilities were given a sendoff by Gulf Oil President William K. Whiteford, and former Army Chief of Staff Matthew B. Ridgeway, who delivered dedicatory addresses.

The new buildings are equipped for research in the automotive, drilling, and nuclear fields. The R. B. Mellon Automotive Products Laboratory consists principally of a series of twenty sound-proof, vibration proof, ventilated rooms in which the operation of all types of internal combustion engines can be studied on an around-the-clock schedule.

"Indoor Turnpike" — Testing of vehicle lubricants and fuels takes place in a 10,000 cu. ft. dynamometer test room.

These test cells are controlled by elaborate instrumentation from consoles located in a central corridor outside the cells themselves. Among them is a variable temperature cell where the operating engine can be exposed to temperatures ranging from those that exist on the hottest summer day to 70 degrees below zero.

Largest of these cells is a chassis dynamometer room that can accommodate a Greyhound Scenicruiser with room to spare. The full size cars being tested in this room can also be exposed to variable temperatures. The engines in all the cells can be operated automatically on most any combination of power and speed requirements to match actual over-the-road performance.

The objective of the work being carried out in the R. B. Mellon Building is to learn how fuels, crankcase oils, coolants and automobile lubricants can be improved for more efficient operation of gasoline engines, diesel engines and gas turbines.

The second of the new buildings is the W. L. Mellon Production Research Laboratory containing 95 laboratories, work shops and offices. The work being conducted here concerns new methods of drilling and taking crude oil from the earth. This involves work in reservoir mechanics, secondary and tertiary recovery, and drilling techniques. Behind the main four-story building is a full scale drilling rig contained in a unique building which protects the laboratory workers from the elements, yet allows actual operation of full size drilling tools.

One of the main targets of this work is the increased recovery of crude oil from reservoirs beyond the current average of 50%. The best secondary recovery methods, gas and water flooding, are used to obtain this figure. There is hope that the in-situ combustion technique, a tertiary recovery method, will allow operators to extract about 85% of the crude in a reservoir.

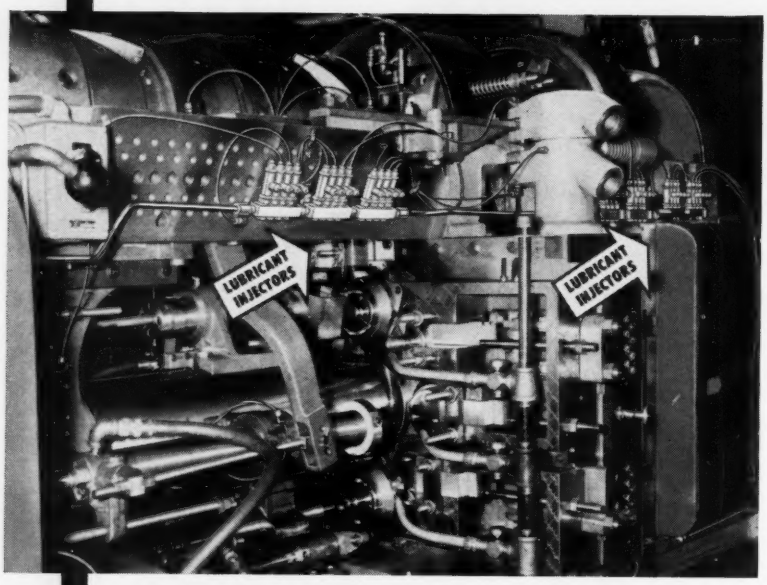
The third new building involved is the A. W. Mellon Nuclear Science Laboratory which houses the 3-million volt Van de Graaff particle accelerator. This instrument, too, is remotely controlled by means of a closed circuit television system by operators who are protected by a five-foot thick concrete wall. This radiation source is to be used to determine the effects of such energy upon petroleum products and to determine how such radiation can be used to aid well-logging and refining.

This Research Center is reported to be the most highly integrated in the petroleum industry and is oper-

Lincoln POWER DRIVE

Reduces Maintenance Costs... Ends Lubrication Down-Time!

Revolutionary Centralized Power-Drive Systems for Automated Machine Groups and Components.



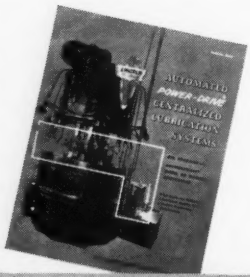
Lincoln "mechanized maintenance" at work: Simultaneously, each time System is cycled, Heavy Duty Way Oil is supplied to lubricant injectors, serving 78 bearings.

Engineered for Positive, Reliable Lubrication

Lincoln's new Power Drive Systems are especially designed and engineered to save you valuable man-hours, boost your production, and put an end to needless repairs. A premeasured film of refinery pure lubricant is automatically applied to bearings at predetermined, self-controlled time intervals. Proven throughout industry in a wide variety of applications, these low-cost systems increase service life of equipment... pay for themselves in no time.

Send for new free bulletin

Complete information on how to "build in" automatic maintenance for automated lines ... machine tools ... production equipment ... and materials handling equipment... Write today for Bulletin 806-R.



Lincoln *Trade Name Registered

THE MOST TRUSTWORTHY NAME IN LUBRICATING EQUIPMENT

LINCOLN ENGINEERING COMPANY
Division of The McNeil Machine & Engineering Co.
5743 Natural Bridge Ave. • St. Louis 20, Mo.

Lube In The News

ated by the second largest oil company in the United States. It now consists of 44 buildings on a 53 acre plot. Approximately 1300 employees, of whom about half are professional, work here. The operating expenses of this highly fascinating and most valuable facility are about one million dollars per month. Approximately 15% of the work being conducted is considered to be basic and fundamental research.

Of particular interest to this reporter were the following instruments or techniques which were observed during the tour of these facilities.

(1) Rotary percussion drill — this holds great promise of allowing considerably faster drilling rates through hard rock than any known drilling technique. It is in the final stages of development and is expected to be offered to the industry very shortly. The heart of this mechanism is a unique "mud-engine" which provides the hammering properties to a conventional rotary drill.

(2) Variable density profile printer — an automatic device which prints a true-to-life cross-sectional picture of underground strata from seismic data in a fraction of the time normally taken by manual plotting.

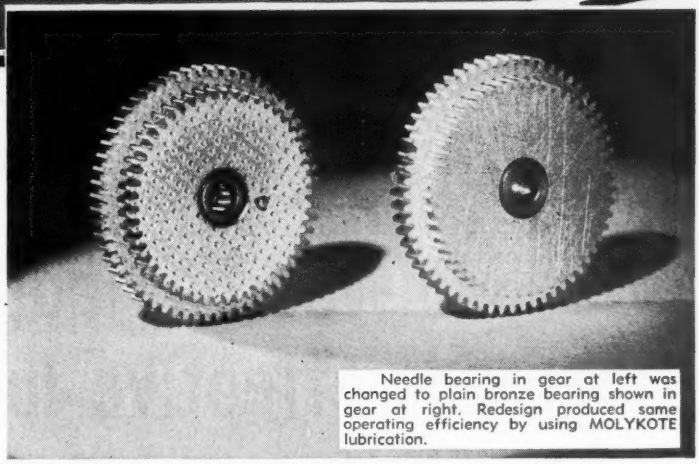
(3) Analytical chemistry — a chemical method for determining oxygen in ethylene in amounts of the order of one part per million and another capable of detecting arsenic in gasoline in amounts of the order of one part per billion.

(4) Hydroisomerization process — method of increasing yield of high octane gasoline.

L. B. Sargent, Jr.
Research Laboratories
Aluminum Co. of America

MOLYKOTE® lubricant sparks design change

SAVES EAGLE SIGNAL CORP., MOLINE, ILL. THOUSANDS OF DOLLARS ANNUALLY



Needle bearing in gear at left was changed to plain bronze bearing shown in gear at right. Redesign produced same operating efficiency by using MOLYKOTE lubrication.

Eagle Signal Corp., Moline, Ill., manufactures the Polyflex Reset Timer, a synchronous motor driven device which trips its contacts open or closed during a time interval. The timer is a precision instrument used to control many industrial operations.

As part of the original design, a gear assembly called for a relatively expensive needle bearing. After experimenting with MOLYKOTE Lubricants, the company adopted a plain bronze bearing, lubricated with MOLYKOTE, which gave the same results as the more expensive needle bearing. The annual saving is estimated at several thousand dollars.

The application of MOLYKOTE, Type M-55, to the bronze bearing shows simplicity of operation as well as the small amount of lubricant needed.

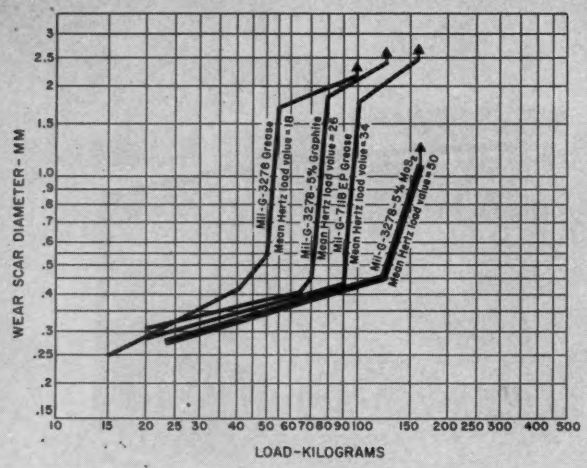
MOLYKOTE, TYPE M-55, IDEAL FOR INSTRUMENT LUBRICATION

Type M-55 is a stable dispersion of sub-micron size molybdenum disulfide powder in a mineral oil. It is approved for mist lubricators and is ideal for instrument lubrication.

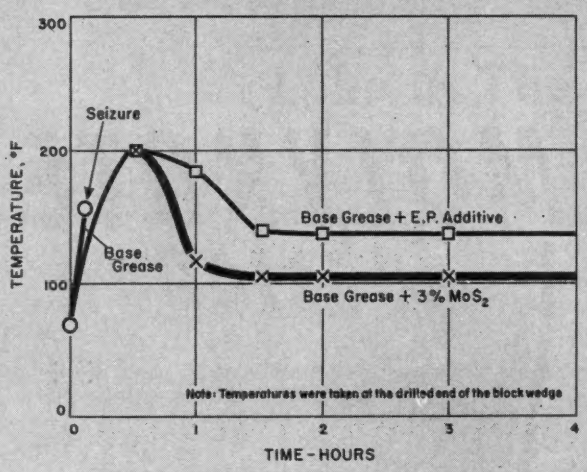
The ALPHA MOLYKOTE Corporation

Main Factories: 65 Harvard Avenue, Stamford, Conn.
71 Arnulfstrasse, Munich 19, Germany

755


WEAR SCAR DIAMETER - MM
LOAD - KILOGRAMS
Mil-G-3278 Grease
Mean Hertz load value = 18
Mil-G-3278 - 5% Graphite
Mean Hertz load value = 26
Mil-G-7118 E.P. Grease
Mean Hertz load value = 34
Mil-G-3278 - 5% MoS2
Mean Hertz load value = 50

4-ball E.P. test shows the superior extreme pressure properties of MoS_2 grease over the same grease without additives. In the same test, grease containing 5% graphite had a mean Hertz load value of 26; the conventional E.P. grease Hertz value was 34.


TEMPERATURE, °F
Seizure
Base Grease + E.P. Additive
Base Grease
Base Grease + 3% MoS2
Note: Temperatures were taken at the drilled end of the block wedge
TIME - HOURS

Timken endurance test clearly shows how MoS_2 functions when added to a base grease. With base grease alone, the specimen seized in about 10 minutes. With MoS_2 added, lubrication was effectively sustained throughout the test at a reduced temperature of about 100°, compared with a temperature of about 130° for the conventional E.P. grease.

Moly-Sulfide additive extends effective lubrication

Laboratory and field tests prove that chassis lubricants containing MoS_2 sustain lubrication after base grease is wiped off

When standard chassis greases are first applied to shackle pins, ball points and other bearing points under trucks, trailers and passenger cars, excellent results are obtained. These greases, however, are subject to mechanical motion, such as reciprocation, pressure, oscillation and shock loading which tend to eject the lubricant.

At this point, chassis grease containing 3% Moly-Sulfide proves its great value. MoS_2 is forced between the rubbing surfaces, adheres to the metal and forms a protective film that prevents galling, welding and fretting. The extent to which MoS_2 sustains lubrication is demonstrated by substantial reduction in wear.

Four tests show how MoS_2 reduces wear

1. **Shell 4-ball extreme pressure test** (see illustration) —MoS_2 addition reduces wear more than 50%, increases load capacity about 70% over base grease.

2. **Falex 2-hour wear test**—As the chart here shows, MoS_2 sustains lubrication, as proved by a reduction in wear, by an average factor of 500.

Grease	Loss in weight of specimen
Lithium-base	1,000 mg.
Lithium-base plus 2% MoS_2	1.98 mg.—average of 3 runs

3. **Timken endurance test** (see illustration)—MoS_2 sustains lubrication well beyond the capabilities of the base grease alone, and at a lower temperature than conventional E.P. grease.

4. **Simulated shackle bolt service test**—oscillating friction machine—3% MoS_2 addition virtually doubles the effective lubrication of a lithium base chassis grease —is far more effective than conventional additions.

Hours to failure—average of 2 tests

Additive	None	3% MoS_2	5% ZnO	15% ZnO
Dry	350	564	336	555
Wet	162	264	109	85

On-the-road use proves MoS_2 prevents chassis wear

A St. Louis company reports no noticeable wear on chassis parts of auto transport trailers, since they selected an MoS_2 chassis grease.

Based on their own tests, several major automobile and truck manufacturers use—and recommend—MoS_2 grease for torsion suspension units, ball joint suspension, as well as for many other critical-wear areas.

Moly-Sulfide greases are available from many producers today. For a list of the manufacturers of these greases—which includes several major oil companies—and for a copy of "Molybdenum Disulfide as a Grease Additive," write to Department 38, *Climax Molybdenum Company, 500 Fifth Avenue, New York 36, N. Y.*

ASPERITIES... *a page of editorial comment and opinion*

Keeping It Simple

Today, almost everyone prepares reports, instructions, proposals, analyses, and related communications for use by others of similar—*but not identical* backgrounds. We assume that the reader of this information has prepared himself equally well to appreciate the argument we voice. Such assumptions can only result in misinterpretation. To communicate with another intellect one must appreciate his limitations as well as his capabilities.

The exchange of technical information between the scientist/engineer and management, between research and sales, between sales and consumer, and in fact, between virtually any two or more groups of different disciplines becomes increasingly difficult as our technology grows. Each group needs different forms of information. Each item of information or communication contains basic assumptions which qualify the background of the communicatee within the disciplines of the communicator. Far too often technical information contains facts, methods, or conclusions beyond the capacity for comprehension by the communicatee. Here the communicator fails.

Authors of technical information can do much to assist publishers and editors in bridging this gap in understanding and appreciation by better definition of the communicatee. Why should the reader want to read this communication? How does it affect him? What action should he take as a result of reading—and comprehending—the information?

Better organization of technical information for the interests of the reader will assist him to develop and broaden his plane of comprehension within a discipline. In terms of simple expression this means more comprehensive summarization of information at the beginning of the communication—tailored to the reader's needs—and development of the supporting data and details afterward. This saves the reader's time while giving him a broad introduction to the arguments, information, and methods presented later. An often overlooked method of treating these details is through the author's bibliography. Why repeat entire reports? If pertinent, the reader will examine the report in his local library.

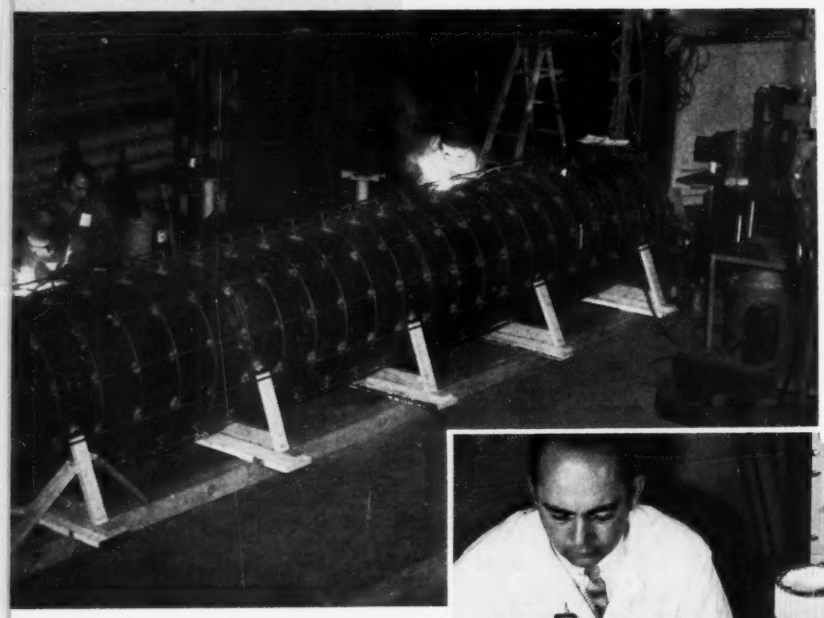
Lubrication Engineering is currently facing many problems involving publication of technical material blanketing the entire science. It is difficult to select the best of numerous excellent papers we receive—especially since ours is an active and rapidly growing technology. The material published must appeal to the greatest number of readers. Often the choice of articles is governed by the ability of the author to express a difficult concept simply.

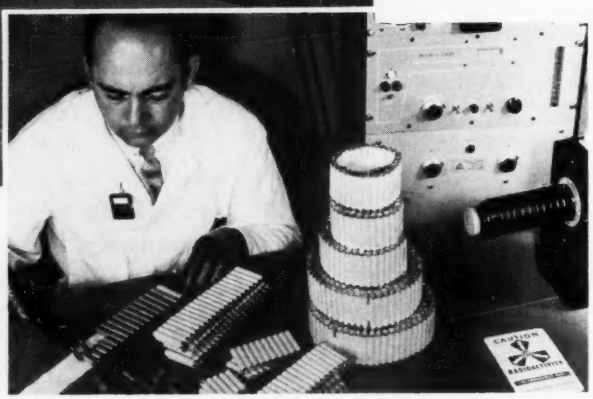
As the aims and interest of the Society broaden so must the journal. Our future issues will reflect this broadened base of interest through papers obtained by the new Joint Industry Councils for publication in the journal. The key to the appeal of these papers is the Industry-wide approach they reflect. Comprehension by our readers will come about only through simplicity of expression, and through greater understanding of the problems of the reader. By publishing more information covering a broader base of activities our publishing standards must become tighter.

As readers, help us serve your needs in the practice and science of lubrication by requesting specific kinds of articles. As authors, help us publish your articles by culling out all information which is not pertinent and by expressing your idea in understandable terms.

R. D. McCormick

L. E. Exclusive





Upper left: Fabrication in progress on 24 foot well for cobalt source housing. Right: Bob Simpson, Inland Radiation chemist, lays out mockup configuration of Iron 59 slugs for final pattern of source.

MORTON GROVE, ILL.:

Dynamic Tests S

TESTING of lubricants where it counts — under intense radiation conditions in a controlled environment—is only one aspect of the aircraft lubricant, fuel, and hydraulic testing program that goes into effect this month at Inland Testing Laboratories, Morton Grove, Ill. Actually, with the unveiling of the new Cobalt 60 "hot cell", reputedly the most powerful source of gamma radiation of its kind in the world, goes a completely integrated program of dynamic lubrication research under "hot" conditions.

Until now, testing of lubricants under simulated nuclear reactor conditions has been largely conducted on a static basis; roughly speaking, lubricants were subjected to gamma or neutron bombardment, and *then* placed in dynamic test machinery. This left one question open: what were the effects of stresses and strains on lubricants *during* radiation bombardment?

Nuclear powered developments such as the atom powered submarine Nautilus, projected aircraft applications, power plants, and projected mobile developments require evaluation of radiation resistant lubricants and fuels under extreme temperature and stress conditions. The unknown variable remained: the effect of radiation on the molecular configuration of lubricants and fuels while undergoing the stresses and changes of actual motion.

To solve this "x factor", researchers at Inland have modified standard testing machinery to operate by remote control in the "hot cell" itself, making it possible for technicians to stand protected outside the 48 inch thick magnetite concrete shielding wall of the chamber at remote instrument panels, while the mechanical test is conducted in the cell.

"The high cost of radiation shielding both in weight and money requires development of materials resistant to radiation damage," declared Dr. Morton Fainman, head of lubrication research at Inland. "Not only does Wright Air Development Center (which initiated this program) require testing of the capabilities of presently available fluids, but the abilities of new materials specifically developed to operate in a radiation field must be determined."

Dr. Fainman, an acknowledged specialist in the field of lubrication research, sums up the problem of gamma radiation testing in a deceptively simple fashion: "The point is . . . to get a dose rate effect comparable to that of a nuclear reactor."

DUPLICATING THE REACTOR

Duplication of the fiercely radioactive environment of a nuclear reactor is the prime concern of engineers and specialists in blueprinting of the "hot cell" itself, since possible configurations of aluminum encapsulated Cobalt 60 slugs vary widely in the effectiveness of the radiation pattern they emit.

Naturally, experimentation with Cobalt 60 in preliminary patterning was next to impossible due to the high radioactivity of the material. Preliminary configurations were tried out with slugs of Iron 59—a faintly radioactive material of much lower radiation intensity than the Cobalt to be used in the final pattern.

These Iron 59 slugs could be manipulated by a specialist using only simple precautions, and from them was developed the highly effective and unique container which will form the heart of the chamber when it goes into preliminary operation this month at Inland. Disposed in a hollow circle 24 inches in diameter, 7000 cobalt slugs obtained from the Chalk River site of the Ca-

Lube

ts Spark Nuclear Program

With the rotation of a bearing in nuclear-powered mobile equipment, movement, stress, and radiation effects combine to create abnormal lubrication conditions formerly only approximated in static tests. Now, unique patterns and methods "build in" the dynamic factor at Inland Testing Laboratories for a new approach to the testing of lubricants under radiation.

UNDER TEST: LUBRICANTS, FUELS, FLUIDS

1. MIL-F-5624C
   Fuels, Aircraft Turbine and Jet Engine Grades JP-3, JP-4, JP-5
2. MIL-F-25656
   Grade JP-6 Turbojet Fuel
3. MIL-F-25558
   Ramjet Fuel
4. MIL-G-3278
   Greases: Aircraft and Instruments (for Low and High Temperature)
5. MIL-G-25013A
   Grease, Ball and Roller Bearing, Extreme High Temperature
6. MIL-H-84459 (USAF)
   Hydraulic Fluid, Nonpetroleum Base, Aircraft
7. MIL-L-6082
   Lubricating Oil, Aircraft Engines
8. MIL-L-7808C
   Lubricating Oil, Aircraft Turbine Engine, Synthetic Base
9. MIL-L-9236A (USAF)
   Lubricating Oil, Aircraft Turbine Engine, High Temperature
10. MIL-L-25336 (ASG)
    Lubricating Oil, Aircraft Turbine Engine, High Film Strength, Synthetic Base
11. MIL-O-5606
    Oil, Aircraft, Petroleum Base

nadian Atomic Energy Commission will duplicate as closely as is now humanly possible the vital heart of a nuclear reactor itself.

MODIFICATIONS IN ORDER

Introduced into this environment will be ten separate pieces of modified test equipment: listed, they are — an Erdco Universal Tester to evaluate performance of fluid lubricants in gears or bearings, modified by removing metal from the front of heads for greater exposure to radiation, replacing seals with graphite and metal bellows, and adding a four-inch thick lead shield to reduce radiation damage to supporting equipment.

A CRC Grease Tester to evaluate the performance of a grease in a bearing at high speeds and temperatures, modified for "hot" use by removing metal from around test bearing and adding remote control attachments.

A WADC Deposition Tester, for evaluation of oil sludging, stability and corrosivity, with the oil test loop detached for mounting inside the "cell".

A One Ball Fatigue Tester, modified with a graphite and metal bellows to reduce radiation deterioration.

A Model C Panel Coker, a Four Ball Fatigue Tester, and a MacMillan Dry Film Tester, with added shielding and controls revised for remote operation.

A Navy Gear Tester, with automation of controls by addition of a Veeder-Root counter to indicate test end and addition of motor shielding.

A Hydraulic Loop Tester and a CFR Fuel Coker, both modified.

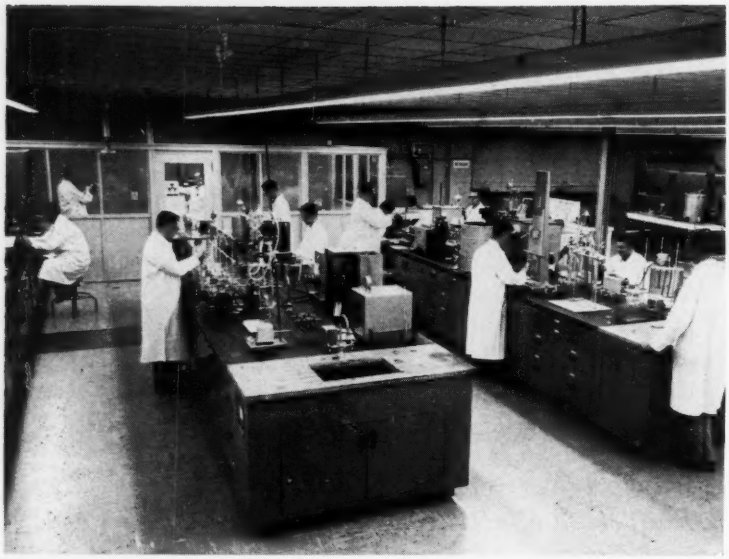
In addition to the set of modified test equipment, a duplicate set of modified machinery will be used, to make certain that modification of the machinery will not affect its behavior. One set will be for dynamic testing in the irradiation environment, while the parallel equipment will be used for screening materials.

In this manner, tests will be run on lubricating oils, greases, ram- and turbojet fuels, and hydraulic fluids to determine efficiency of behavior in the presence of a radiation field, adding greatly to the relatively small store of information on the behavior of these products under dynamic conditions. Although considerable data on organic aircraft-type fluids exist, the preponderance is on material that was statically "irradiated" and *then* evaluated.

"Actually," continued Dr. Fainman, "we will be in a position to determine what the aircraft engine 'sees' under radiation, including the deposition tendencies of lubricants, high speed bearing effects on greases and oils, and other phenomena.

"Because seals, packings, and other components of standard test equipment simply 'go to pot' under radiation, intensive modification was required. One test advantage that we do have, however, is that the effects of radiation on the test machinery are transient, as compared to the permanent effects of induced artificial radio-activity caused by actual nuclear bombardment. This means we can stop and start our tests practically at will, study the mechanism of failure and get the maximum usage out of the facility.

"This is a terrifically expensive environment", he pointed out, "and we want to make sure we get optimum performance. Allied to these economic considerations, and even more important, is the question of



Modern laboratory equipment *plus* radiation facilities equal integrated dynamic lubricant testing. The fully-equipped chemical laboratory above will evaluate tests and operate in conjunction with the "hot cell" itself. Both inside and outside the "cave" complete precautions are taken to prevent over-exposure to radiation, including film badges, radiation checkers, and Geiger counters.

adequate safety measures in radiation environments.

MYTH AND SAFETY

"For some people", continued Dr. Fainman, "dangers from a radiation source have assumed the exaggerated proportions of a myth. They have come to feel, through over-absorption of popular literature which plays up for its own purpose the 'perils of radioactivity', that a radiation facility cannot be safe because of its very nature.

"We have insured the safety of our personnel here by a number of interrelated measures, all of which supplement each other for realizing the greatest protection to individual personnel.

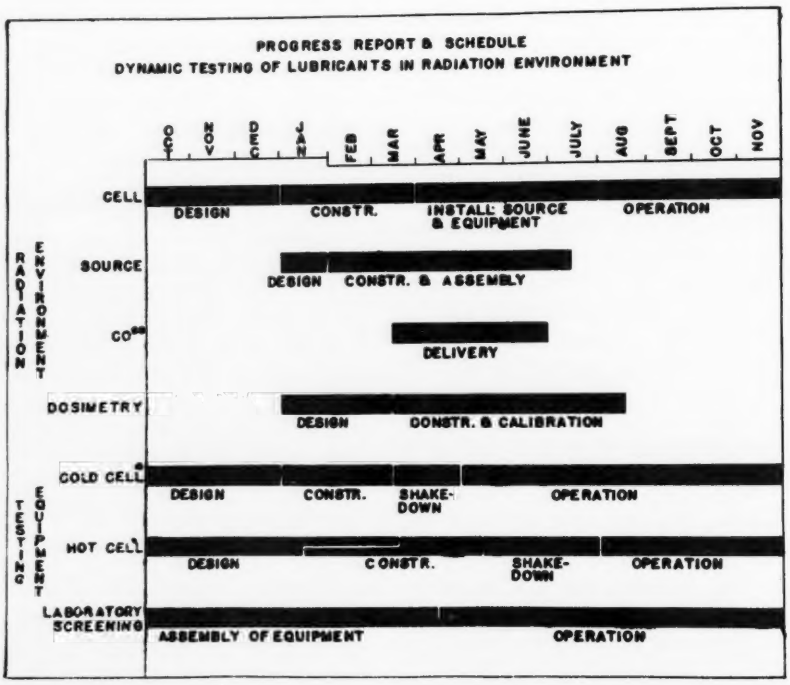
"A 'fail-safe' mechanism on all moving cell components insures complete protection in the case of electrical or mechanical failure. For example: as opposed to many radiation facilities, we have designed our radiation source to be brought up to the test equipment, instead of lowering the equipment into the water shield. The Cobalt 60 source is lowered into a 24 foot water-filled well by a chain driven elevator, and brought up by the same means after test equipment is introduced into the cell. This enables us to conduct dynamic tests that would be impossible under water. In the event of hydraulic failure for any possible reason, a magnetic clutch is released, dropping the entire source back into its shielding environment and making it perfectly safe for personnel to enter the chamber itself.

"All our equipment operates on this 'fail-safe' basis," pointed out Dr. Fainman. "In addition, double-check safety measures are provided by explosion-proof chambers for the testing of fluids under high pressure, a complete air-conditioning unit for the "hot cell" which keeps pressure down and prevents the escape of any radio-active material into surrounding areas, and tell-tale film badges which measure the amount of radiation to which each technician is exposed."

BUILDING THE CELL

The shape of the cell itself is that of a cube 16 feet on each side. Three walls are poured concrete 68 inches thick, with the 48 inch front wall and door ¼ inch steel plate shells, filled with high density magnetite concrete, and a roof of 58 inch poured concrete. Although radiation emitted from the source will total 62,100 curies, shielding is designed on the basis of a 100,000 curie point source, providing an additional safety factor.

A number of unique features



have been incorporated in the cell. An original 48 inch thick glass window has been replaced by a 36 inch standard window and an 11 inch glass pane, increasing viewing angle by four degrees, and, incidentally, reducing cost by $4,300.

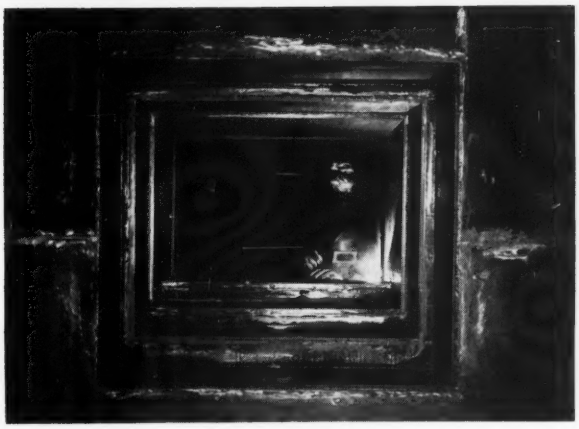
Manipulators, a second pair of radiation-proof hands operated by remote control from outside the "cave", are more flexible than the conventional type due to a side indexing feature which permits coverage of a larger working area.

Sixty-six access holes built into the facility increase its versatility for immediate and future operations by providing entrance points for conduiting, observation, ducts, cameras, and other ancillary equipment. In conjunction with the cell, an 8000 square foot laboratory facility will house the general chemical laboratory, an isolated radiochemical laboratory, an explosion-proof cell arrangement for high pressure and hydraulic testing, and a set of test machinery duplicating those to be used in the radiation cell.

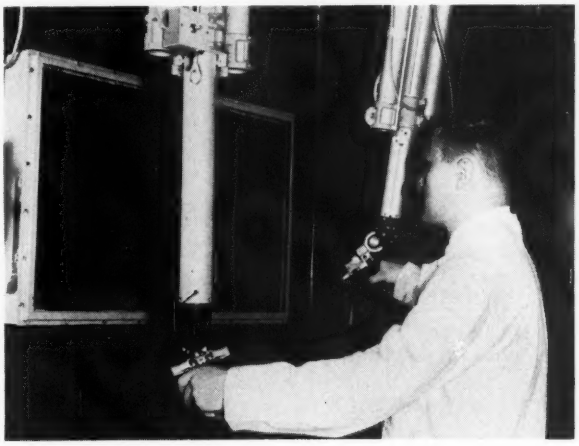
POSSIBILITIES AND POTENTIALS

"Not only will we be able to perform tests and underline significant deviations with the new facility, but also develop new testing methods for lubricants and fluids in the radically new environment of nuclear-powered mobile equipment," continued Dr. Fainman. "Both petroleum-based and synthetic lubricants and hydraulic fluids can be evaluated, suggestions made as to new lines of product development, structures of fluids related to performance, and trouble shooting on a custom basis made available to all users.

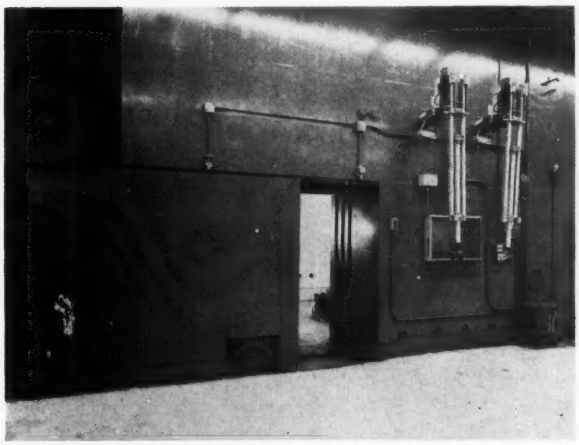
"In point of fact, our being a private facility in a sense makes it imperative that we come up with the answer to any problem submitted," he concluded. "The flexibility we have built in both facility and programming will, we feel, enable us to come up with more and better answers in the future to the critical problems of the effects of radiation on the *dynamic* behavior of synthetic esters, silicones, greases (both petroleum-based and synthetic) and a wide variety of presently existing and potential lubricants in the key area of nuclear-powered mobile equipment."



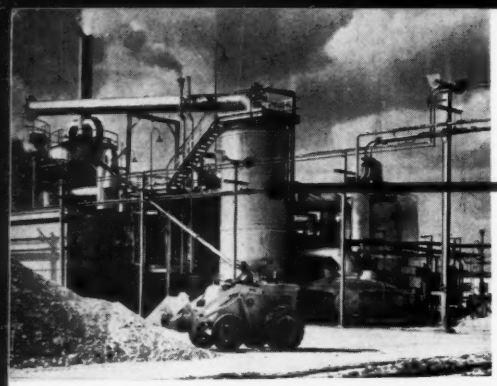
Constructing the unique faceplate well for the observation window of the "cave". Dehumidifiers are installed between sheets of glass to eliminate fog.



A technician at the manipulator controls and faceplate of the cell. Note side indexing feature (upper left) permitting greater latitude of movement.



The front wall of the cell, showing movable steel frame, magnetite-filled door with "fail safe" mechanism. Portion of source is visible through door.



James River Works near Richmond, Va.
(operated by Grasselli Chemicals Dept.)

3

Du Pont's Program:

Special lubrication programs have been designed for the 3 types of plants illustrated. Shown above is a small single unit sulphuric acid plant. A single unit large polyester fiber mill is at the right. Also, below, an 8-acre diversified chemical and dye plant.

Du Pont's Textile Fibers mill
near Kinston, N. C.

Chambers Works of Du Pont's Organic Chemicals Dept.,
Deepwater Pt., N. J.

THE KEY MAN in any plant lubrication program is the lubrication engineer. In the chemical industry in particular, highly integrated operations are increasing in number, and the failure of one mechanical component can result in large production losses. Although the total amount of lubricant used is small in comparison to some other industries, proper lubrication is essential to continuous and economical operation of mechanical equipment.

In various DuPont facilities, experiences have demonstrated that an engineered lubrication program in a chemical plant can reduce lubricant and labor costs as much as 50 per cent.

One DuPont plant (above, right) used 46 oils and greases before planned lubrication, maintained a supply of each in their stores valued at $3000, and spent over $10,000 annually for lubricants. Each of eight area maintenance foremen had his own lubrication mechanics — a total of 11 men. *Because eight men were responsible for lubrication eight different oils might be used in the same service in different parts of the plant.*

An engineered lubrication program was established which included

Benefits of Engineered Lubrication:

1. Reduction of number of lubricants from 46 to 16
2. Decrease in annual lubricant cost from $10,000 to $6,000
3. Personnel needed cut from 11 to seven
4. Reduction of stores inventory from $3,000 to $1,300

Planned Lubrication for Three Plant Types

by R. W. Clark, Maintenance Engineering Section, E. I. du Pont de Nemours & Co., Inc.

placing the responsibility for lubrication of the entire plant under a lubrication engineer who supervises the lubrication mechanics. Today, seven lubrication mechanics do the work formerly handled by 11 men. Annual lubricant cost is less than $6000, and a total of 16 oils and greases is used having a stores value of $1300.

A second example is a large diversified plant that employs a staff lubrication engineer and 13 lubrication mechanics. Eighteen months after a completely engineered lubrication program was put into effect, *this plant realized an $18,000 annual reduction in lubrication, labor and material costs.*

THREEFOLD LUBRICATION

In over one hundred plants and laboratories, the DuPont Company employs three distinct approaches to planned lubrication. Installations of the company vary in size and lubrication requirements. Plant personnel number from less than twelve to over 6000; products manufactured range from one to several hundred. Separated organizational procedures are required to tailor lubrication to diverse plant functions.

Basically, DuPont plants are classified in two groups. The first type usually manufactures one product and has well-integrated operations, with manufacturing areas in close proximity. In the second, non-integrated type of plant, manufacturing areas are widely dispersed and produce a variety of products. A third approach, employed in very small plants, is indicated because of limited availability of personnel.

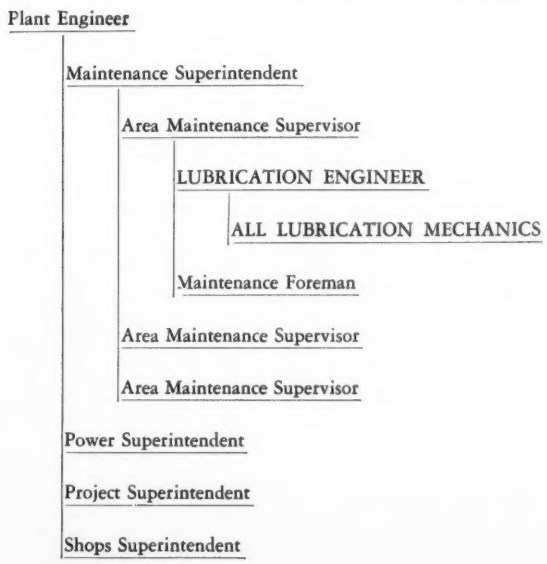
In the case of one large diversified plant with several hundred buildings, there are many separate manufacturing areas handling unrelated products and processes. Each maintenance supervisor is responsible for all maintenance in several of the manufacturing areas, and has one or two mechanics to handle equipment lubrication.

In very small plants, it is sometimes necessary to use a third method. In this case, manufacturing personnel or operators handle the routine daily lubrication assignments, and maintenance personnel handle oil changes and any special lubrication work. *This is the least desirable arrangement since there is a split responsibility, and it is difficult to control the lubrication activity.*

Integrated chemical plants which produce one product, such as cellophane or synthetic textile fibers, lend themselves well to a centralized lubrication group. The plant lubrication engineer is a member of line organization and responsible for all plant lubrication. All plant lubrication mechanics report to him. The smallest centralized plant lubrication group in the company has four mechanics, and there are twelve in the largest. (Chart No. 1 shows the location of such a group in the plant engineering organization.)

The second type of chemical plant is non-integrated with diversified operations. Here, lubrication personnel are usually de-centralized (Chart No. 2). Each maintenance supervisor is responsible for the lubrication in this area, and has his own lubrication mechanics.

CHART 1. PLANT ENGINEERING ORGANIZATION
CHART FOR INTEGRATED PLANT



Reporting to plant engineer, maintenance superintendent, or project superintendent, the lubrication engineer provides area maintenance supervisors with schedules, helps with specific problems, and co-ordinates all lubrication activity in the plant.

ORGANIZED LUBRICATION PROGRAM

The lubrication engineer must establish the necessary organization, see that it functions efficiently, and have an understanding of the following items:

1. *Lubrication and theory and lubricant selection.*
2. *Physical and chemical characteristics of lubricants.*
3. *Lubrication scheduling.*
4. *Purchase, storage, and inventory of lubricants.*
5. *Operating characteristics of the plant equipment — This requires a thorough understanding of the mechanical components of the plant equipment.*
6. *Operating conditions and environment — Ambient temperature and possibility of contamination will affect the choice of lubricant and the lubrication frequency.*
7. *Process materials being handled — A lubricant must be used which would not cause contamination if it leaked into the product. Likewise, if the process material could leak into a gear case or bearing, the lubricant must not be affected adversely.*
8. *Lubrication equipment — This includes selection, operation and maintenance of lubricant handling and dispensing equipment.*
9. *Current developments — This includes evaluation of new petroleum, synthetic and solid lubricants as they are developed and offered commercially.*

While the lubrication engineer requires this knowledge to establish and operate the plant lubrication organization, he must also provide adequate direction for the lubrication mechanics. The program can be successful only when the lubrication mechanics are well informed, conscientious, and have the correct attitude toward their work.

SCHEDULES AND TRAINING

The technique which insures the success of the lubrication organization is proper planning and scheduling.

To insure that these personnel have adequate knowledge and realize the importance of their job, organized training in lubrication and mechanical fundamentals is necessary. A conscientious, well-trained lubrication mechanic is an excellent preventive maintenance inspector. He sees the equipment frequently, and can report incipient malfunction of components, resulting in scheduled repair rather than emergency shut-down.

The master lubrication schedule should list every piece of equipment in the plant by name and number, the name of each part to be lubricated, the lubricant to be used in each part, frequency of application, and oil change periods.

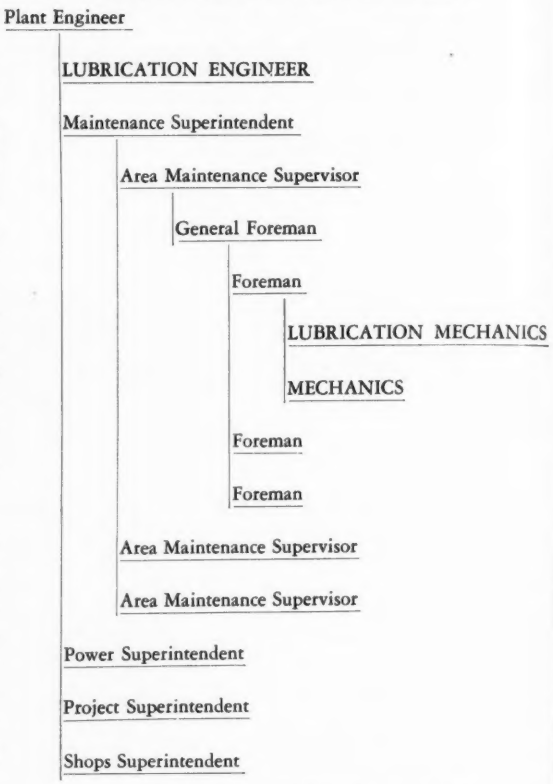
Operating conditions and environment may influence a change in this frequency. Schedules should be reviewed periodically and revised.

SELECTION OF LUBRICANTS

The final item to be considered in establishing and operating the plant lubrication organization is lubricant selection.

Chemical plant equipment includes agitated reaction vessels, pumps, fans, compressors, grinders, blenders, and similar equipment. In spite of this wide variety of equipment the same machine elements require lubrication: gears, bearings, chains, sliding surfaces.

CHART 2. PLANT ENGINEERING ORGANIZATION CHART FOR DIVERSIFIED PLANT



As shown on Chart No. 3, the common industrial oils account for 98% of the total fluid lubricants in DuPont plants.

Some of the miscellaneous oils which account for 2% of the fluid lubricants used include the following: silicones, polyalkylene glycols, fluorinated hydrocarbons, diesters, phosphate esters.

The silicones are used if a high viscosity index fluid is required, including damping media and certain hydraulic systems. Silicone fluids are used where there are high operating temperatures or exposures to methanol and other chemicals which would degrade petroleum oils.

(Continued on p. 414)

CHART 3. FLUID LUBRICANTS USED BY CHEMICAL PLANTS

TYPE OF LUBRICANT	PER CENT OF USAGE
High quality industrial oils	30
General purpose machine oils	20
Cylinder oils	20
Turbine and hydraulic oils	15
Heavy duty motor oils	10
Refrigeration and vacuum pump oils	2½
Extreme pressure gear oils	½
Miscellaneous fluid lubricants	2

CHART 4. GREASES USED BY CHEMICAL PLANTS

TYPE OF GREASE	PER CENT OF USAGE
Calcium base	50
Sodium or mixed base	35
Miscellaneous	15

Lube Lines

by A. F. Brewer

TEMPERATURE CONTROL

In the discussion of operating conditions mention was made of the operating temperature at bearings or in gear housings, and the desirability of employing means for control of these temperatures. Aside from methods of controlled lubrication which are built right into the lubricating system, and which in reality control the amount of lubricant being circulated or fed to the bearings, control of the lubricant temperature is one of the most effective ways of promoting dependable lubrication.

There is a mean average temperature range over which any lubricant will function most effectually. This range of course will vary according to the type of the machine and the conditions under which it must operate; it naturally will be higher in steel rolling mill or metal forming service than in low temperature rock crusher service or in cold room conveyor work. So the temperature of the unit may have to be raised or lowered to enable the lubricant to function properly. Water circulating through suitable jackets or piping is utilized. The size or extent of the heat transfer facilities depends upon the expected temperature range and the amount of heat involved. In the oil cooling facilities of a circulating oiling system on a steam turbine, cold water removes the heat and brings down the bearing temperature to a safe range — say from 150 to 180° F. In a gyratory rock crusher operating under low temperature conditions, lubrication of the drive gears and support bearings is assisted when starting up by circulating hot water through the coils in the base of the oil reservoir.

The use of air cooling is practicable where air flow can be induced over or around the lubricated part which must be cooled. Fans or blowers accomplish this most effectually, although the amount of cooling which can be expected depends upon the inlet temperature of the air and the volume which can be put into circulation. Fan or blower capacity is very important in this respect just as pump capacity is important in a water cooling system.

Obviously, air cooling is most effective on mobile machinery where it can be used as an adjunct to water cooling via radiators. Where a unit such as a portable stationary compressor is operating, fan and radiator capacity are larger with respect to engine or compressor size than on a moving vehicle where forward motion helps to draw air through the radiator. Where the parts to be cooled are in the same plane with respect to the air stream, and there is little chance of some being exposed to heated air from others, air cooling is effective in proportion to the temperature of the air stream.

The nature of the lubricant of course becomes a factor in connection with cooling. In some types of service flow of lubricating oil through bearing clearances or over gear teeth promotes heat transfer, the oil acting as an auxiliary coolant. In small self-contained units the oil in circulation does the entire job of transmitting heat from gears, chains, or bearings to the walls of the case, at the exterior of which the surrounding air takes over the chore of additional heat removal to keep the inner mechanism at a safe operating temperature.

It is the responsibility of management to insist that temperature control of plant unit lubricating systems be adequate, whatever the cooling media, in order that the lubricants can function without undue overload. Present-day anti-oxidation and extreme pressure additives cannot do all the work. *Never* assume that any industrial lubricant is an all-temperature type. Modern lubricants have a wider range of temperature service, than ever before, over which they will function dependably, but still there are limits.

HIGH TEMPERATURE BEARING APPLICATIONS

During the past twenty years thinking and practice in regard to the benefits to be obtained from high temperature bearing service have been conspicuous by progress. Where formerly 400° F. was the customarily accepted maximum, particularly when petroleum base lubricants had to be relied upon, today, according to Arno H. Shepardson, writing in a recent issue of The Bearing Engineer,* "It is not uncommon . . . to have applications in the 500° F. to 1200° F. range".

The requirements of aircraft installations have probably had the greatest influence upon this trend, especially in connection with bearings for jet engine controls. Mr. Shepardson states that,

> "Ordinarily, these high-temperature bearings must be operated dry. Fluid lubricants are of questionable value above 400° F. The residue from unsatisfactory lubricants is more harmful than operating without lubrication, so provision is made neither for lubrication to protect the surface nor for relubrication.
>
> "There are other high-temperature difficulties. Metals oxidize and scale. Bearing parts undergo differential expansion. Consequently, high-temperature aircraft bearings are given higher internal clearances. The amount of clearance depends upon the size of the bearing elements and the amount of scale which can be tolerated."

This trend quite naturally has required intensive study of materials, the effect of scale as it may relate to friction and the effect of elevated temperatures on hardness of the materials. Certain types of stainless steels are mentioned as being used with reasonable success. It is to be expected that research in the field of high-temperature lubrication can contribute data which will possibly have a valuable relationship to this research in the fields of bearings and metals, particularly in industries other than the aircraft, where provisions for relubrication of high temperature bearings could be more readily provided.

*Published by The Torrington Company

Some Effects of Gamma Radiation on Commercial Lubricants

In order to survey their utility in atomic reactors, twenty-eight lubricants were exposed to gamma rays. Included were four base oils (pale oil, neutral oil, white oil, and bright stock), four industrial oils, two gear lubricants, an automatic transmission fluid, three industrial greases, and three multi-purpose greases. Exposures ranged from 10^8 to 9×10^8 roentgens at about 80°F. Tests showed that the effects of radiation on compounding in lubricants are probably more limiting than the effects on the base oil. Certain commercial lubricants are useful for a gamma dosage of at least 10^8 roentgens.

J. G. Carroll and S. R. Calish, Jr.
California Research Corporation
Richmond, Calif.

The atomic reactor business is booming! Since completion of the first nuclear pile at the University of Chicago in December 1942, some 45 reactors have been built. By 1960 about 127 more are planned for completion[1], excluding aircraft power reactors and those used to produce fissionable material. A growing number of these new energy sources are designed for central power station use.

The arrival of the atomic era has created new technical fields, particularly related to materials. Lubricants and lubrication for the atomic age have also received considerable attention. For example, it is known that nuclear radiation causes drastic changes in lubricants and that certain types of organic compounds are superior to mineral oils in radiation resistance[2]. However, current literature has not sufficiently emphasized the role of existing lubricants. Are lubricants which are commonly used in everyday industrial practice to be completely useless in atomic applications? May they be useful up to a point? If so, what is this point?

Such questions prompted a survey of the radiation resistance of commercial lubricants. Several mineral oils typical of large refinery production were included, along with twelve compounded lubricants. These represent a cross-section of industrial, marine, and automotive lubricants. Many contain typical compounding dictated by the present knowledge of the art and the requirements of the job to be done. Similarly, seven greases were included in the survey. Though designed for specific jobs, all lubricants are of familiar types. All represent current production and were taken "off the shelf."

TEST CONDITIONS

Samples were irradiated in the commercial gamma source at the Materials Testing Reactor (MTR) in Idaho. Spent fuel elements from the reactor are placed in a grid framework under 20 feet of water for shielding. Experimental specimens are placed within this grid for irradiation with gamma rays alone. Gamma radiation was chosen as it will predominate in applications in reactor accessory equipment. Also, gammas do not produce residual radiation as do neutrons which leave most materials radioactive. Thus, samples may be inspected after gamma irradiation with a minimum of health hazards.

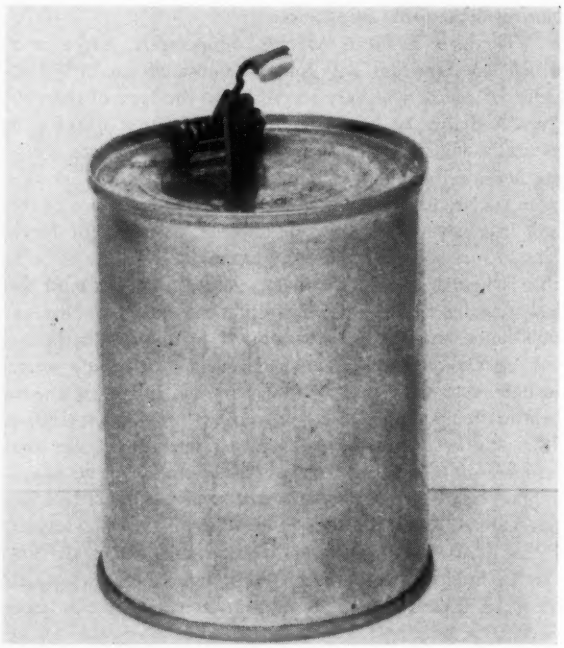


Figure 1. Sample Container.

Gamma exposures usually are expressed in terms of the roentgen, (r)[3], which may be considered as a quantity of absorbed gamma energy per unit of material irradiated. One Btu per pound is about equivalent to 2.75×10^5 r. The average gamma flux in the MTR facilities was about 2×10^6 r per hour. Dosages (flux $\times$ time) of 10^8 r to 9×10^8 r were used. These dosages required exposures from 50 to 450 hours. The flux was monitored by established techniques[4], and values cited for gamma dosages are accurate to about $\pm$ 10%.

About 150 grams of the material to be irradiated were placed in a common "baby food" can of the tin-plated, unlacquered type, size 00. The lid with a small drilled vent hole was then crimp-sealed to the can. The vent was provided with a simple pressure relief valve to release pressures greater than 2 psi. The container is shown in Figure 1. The vent was used to prevent rupture of the can by gas evolved from the lubricant sample during irradiation[5].

Seven sample cans were placed in a 3-inch O. D. vented canister and inserted into the MTR gamma grid. Average temperature during exposure was about 80° F.

Above the level of about 5×10^6 *r* to 10^{10} *r*, organic fluids and greases are sensitive to radiation. Below 5×10^6 *r*, damage to oils and greases is usually negligible; above 10^{10} *r*, only the most resistant organic structures survive. By comparison, 200 to 800 *r* total body dosage is considered lethal to humans[6].

EFFECTS OF RADIATION ON OILS

Tables I, II, and III summarize the test results on oils. Radiation caused all oils to darken and to acquire an acrid odor similar to that of highly oxidized oils. Although radiation accelerates oxidative damage[7], neutralization numbers after irradiation did not rise above 0.5. In some cases a slight floc or haze was noted. No sludge was evident.

Radiation is known to increase the viscosity of organic fluids[2]. Typical changes for the base oils are shown in Figure 2. In this dosage range (up to 7×10^8 *r*), almost a straight line relationship exists between the logarithm of viscosity and gamma dosage. As with oxidation resistance, the radiation resistance of medicinal white oil, such as the 95 VI paraffinic material in Table I, is poor. At 10^8 *r*, this oil increased in viscosity at 100° F by 43 percent. With the other three, the increase was less than 12 percent.

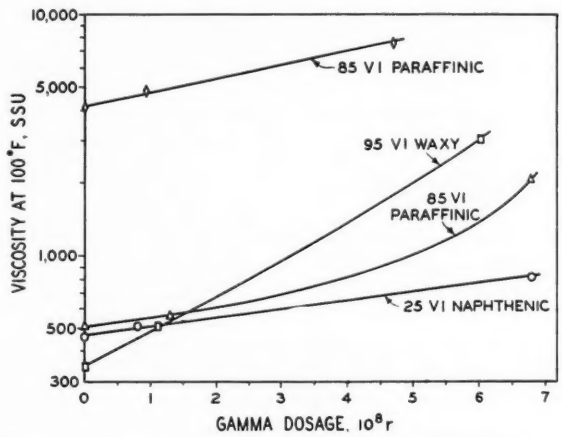


Figure 2. Viscosity Change of Base Oils with Irradiation.

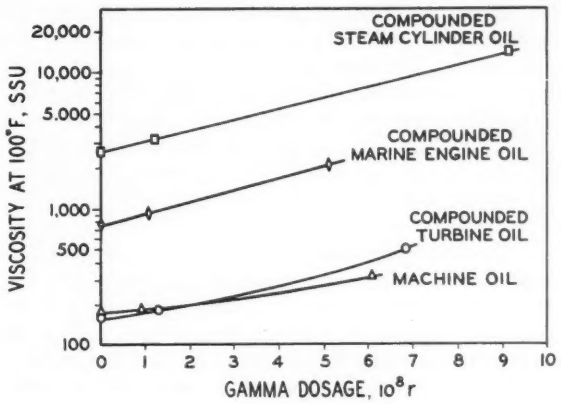


Figure 3. Viscosity Change of Industrial Oils with Irradiation.

Similar information is in Figure 3, which shows viscosity change for the industrial oils. The curves for all four oils have approximately the same slope, indicating similar susceptibility to radiation. At 10^8 *r*, increases in viscosity at 100° F range from 5 to 18 percent.

Figure 4 illustrates that radiation tends to increase the viscosity index of lubricating oils. This effect was observed

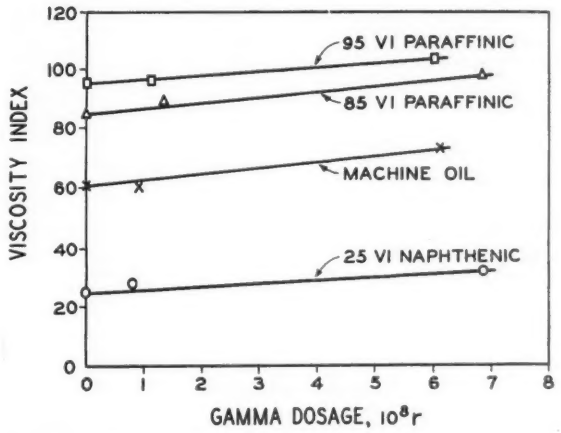


Figure 4. Effect of Irradiation on Viscosity Index.

TABLE I. PROPERTIES OF TYPICAL BASE OILS

Description	25 VI Naphthenic			85 VI Paraffinic			95 VI Paraffinic			85 VI Paraffinic		
Type of Oil	Pale			Neutral			White			Bright Stock		
Dosage, $10^8 r$	0	0.8	6.8	0	1.3	6.8	0	1.1	6.0	0	0.9	4.7
Gravity, °API	22.5			28.2			30.4			24.6		
Flash Point, COC, °F	385			485			450			600		
Fire Point, PM, °F	420			540			525			675		
Viscosity, ssu												
at 100°F	466	514	809	521	560	2160	350	513	3016	4350	4843	7606
at 210°F	53	55	64	62	65	148	55	64	182	192	202	282
Viscosity Index	25	28	32	85	89	99	95	96	103	85	84	90
ASTM Pour Point, °F	−15			+5			+10			+10		
Neutralization No.	0.01	0.03	0.06	0.01	Nil	Nil	0.02	Nil	Nil	0.06	0.01	0.10
Carbon Residue, %	0.08			0.02			0			0.70		
ASTM Color	3−	3.5	5.5	2−	3	6	0.5	1.5	2	7	8−	8
Falex EP Test, lb.										1450		1800

for all oils irradiated, with one notable exception, the automatic transmission fluid shown in Figure 5. This contained a high molecular weight polymer as a Viscosity Index (VI) improver. The initial decrease in viscosity was due to the breakdown of this polymer, which was accompanied and followed by the usual polymerization of the base oil. The dotted line of Figure 5 represents the probable pattern of viscosity change; note the steep slope after 5×10^8 *r*.

Gamma irradiation at the levels used appeared to improve the wear characteristics of the oils tested. In Almen wear tests with bronze on steel (see Tables II and III), the weight loss of the bronze pin was consistently less for lubricants after irradiation than before. Similarly, Falex extreme pressure tests, steel on steel, gave somewhat higher values after exposure. This is particularly interesting on compounded oils, as it indicates that the effectiveness of the compounding was not lost even though radiation

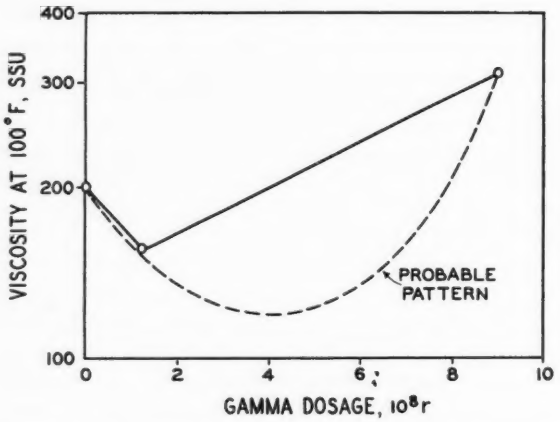


Figure 5. Radiation Damage to a VI-Improved Automatic Transmission Fluid.

TABLE II. PROPERTIES OF TYPICAL INDUSTRIAL OILS

Description	Turbine Oil			Machine Oil			Steam Cylinder Oil			Marine Engine Oil		
Type of Base Oil	Naphthenic Pale			Naphthenic Pale			Paraffinic Bright Stock			Naphthenic Pale		
Oxidation Inhibited	Yes			No			No			No		
Other Compounding	Yes			Yes			Yes			Yes		
Dosage, 10^8 *r*	0	1.3	6.8	0	0.9	6.1	0	1.2	9.1	0	1.1	5.8
Gravity, °API	29.6			24.6			22.5			20.2		
Flash Point, COC, °F	350			355			535			400		
Fire Point, PM, °F	385			410			600			460		
Viscosity, ssu												
at 100°F	159	182	494	175	183	328	2627	3248	14,252	768	985	2180
at 210°F	43	45	63	43	44	52	150	170	491	61	72	121
Viscosity Index	89	93	95	60	60	74	91	91	103	74	77	81
ASTM Pour Point, °F	−15			−10			+20			−15		
Carbon Residue, %	0.01			0.02			2.2			0.35		
Neutralization No.	0.05	0.01	Nil	0.04	0.50	0.50	0.12	0.08	0.05	0.14	0.14	0.12
ASTM Color	1−	2−	3.5	2−	Blk	Blk	8+	8+	8+	8−	7−	8+
Corrosive to Copper	No		No	No	Yes	Yes	No	No	No	No	No	No
Falex EP Test, lb.	1600		1750	1700		4000						
Almen Wear Test, mg				1.0		0.7						

TABLE III. PROPERTIES OF TYPICAL GEAR LUBRICANTS AND A TRANSMISSION FLUID

Description	Industrial Gear Lube			MIL-L-2105 Gear Lube			Automatic Transmission Fluid		
Type of Base Oil	Paraffinic			Paraffinic			Naphthenic		
Oxidation Inhibited	No			No			Yes		
Other Compounding	Yes			Yes			Yes		
Dosage, 10^8 *r*	0	1.1	8.2	0	1.1	6.0	0	1.2	9.0
Gravity, °API	21.0			24.3			29.4		
Flash Point, COC, °F	490			450			315		
Fire Point, PM, °F	540			510			360		
Viscosity, ssu									
at 100°F	1295	1562	4848	929	1087	1741	200	155	315
at 210°F	106	119	273	84	87	119	50	44	56
Viscosity Index	101	102	109	94	84	94	134	115	114
ASTM Pour Point, °F	+10			+5			−35		
Carbon Residue, %	3.8			0.74			0.70		
ASTM Color	Blk	Blk	Blk	4.5	Blk	Blk	7	7	8−
Corrosive to Copper	No	No	No	No	Yes	Yes	No	No	No
Falex EP Test, lb	1900		1950	4500+		4500+			
Almen Wear Test, mg	1.5		1.2	2.4		0.8			

damage occurred. However, oils with chlorine-containing additives, such as used in MIL-L-2105 gear lubricants, became very corrosive. There was indication of evolution of HCl during irradiation. There also was severe corrosion on the baby food cans.

EFFECT OF RADIATION ON GREASES

Tables IV and V summarize the test results on greases. Typically, radiation altered the dropping point and the consistency of lubricating greases. Dropping point changed by —85° F to +40° F; two greases did not change significantly. All greases softened in this dosage range. Three of the six greases reported reached the semiliquid state (500+ penetration). Figure 6 shows the change in consistency for four greases. At 10^8 *r*, note that the grease gelled with the sodium synthetic (sodium N-octadecyl terephthalamate) did not increase in consistency. The rate of change varied and depended on each combination of oil, gelling agent, and additive. Other work has shown that this trend toward fluidity reverses at higher gamma dosages and eventually greases become solid[8]. Those greases which showed pronounced changes in physical properties also showed a drastic change in fiber structure of the gelling agent. Figure 7 illustrates this change at 11, 150 magnification for the sodium soap grease.

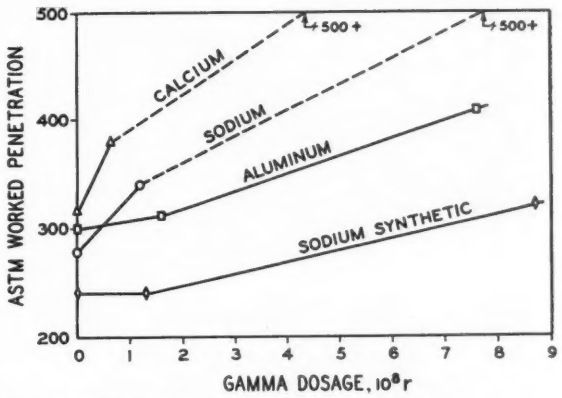


Figure 6. Effect of Irradiation on Grease Consistency.

Irradiation has been shown to reduce markedly the oxidation resistance of greases[8]. Typical bearing life[9] is

TABLE IV. PROPERTIES OF INDUSTRIAL GREASES

Gelling Agent, Type	Sodium Soap			Calcium Soap			Aluminum Soap		
Per Cent by Weight	28			18			11		
Oxidation Inhibited	Yes			No			No		
Other Compounding	No			Yes			No		
Dosage, 10^8 *r*	0	1.2	7.7	0	0.6	4.5	0	1.6	7.6
ASTM Dropping Point, °F	450	456	448	240	155	234		265	
ASTM Penetration, 77°F									
Unworked	237	227	200	278	305	368	220	292	389
Worked	280	342	500+	317	382	500+	300	313	411
Mineral Oil Properties									
Flash Point, PM, °F	480			340			425		
Viscosity, ssu at 100°F	490			6..			1175		
ASTM Pour Point, °F	+10			0			—10		

TABLE V. PROPERTIES OF MULTIPURPOSE GREASES

Description	Automotive			Industrial			Aircraft		
Gelling Agent, Type	Lithium-Calcium Soap			Sodium Synthetic[a]			Lithium-Calcium Soap		
Per Cent by Weight	10.5			12			16		
Oxidation Inhibited	Yes			Yes			Yes		
Other Compounding	Yes			Yes			Yes		
Dosage, 10^8 *r*	0	0.9	6.7	0	1.3	8.7	0	1.3	8.7
ASTM Dropping Point, °F	340	367	358	500+	500+	500+	380	385	420
ASTM Penetration, 77°F									
Unworked	290	280	284	206	199	227	277	307	376
Worked	292	340	405	241	242	323	319	361	500+
Mineral Oil Properties									
Flash Point, PM, °F	410			500			340		
Viscosity, ssu, at 100°F	1090			625			140		
ASTM Pour Point, °F	—10			+5			40		

a. Sodium N-octadecyl Terephthalamate

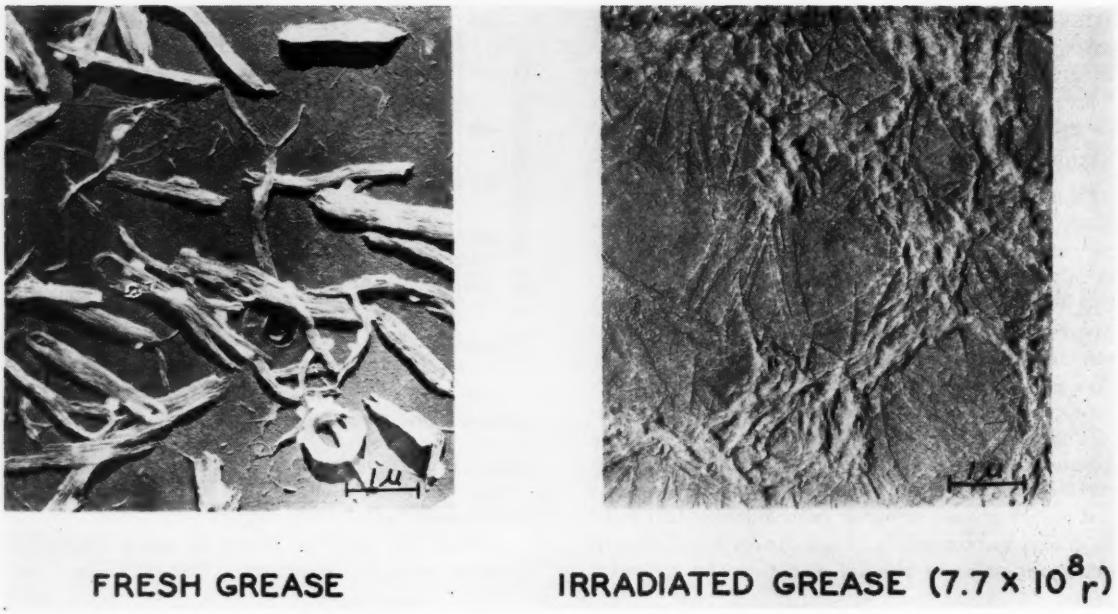


Figure 7. Effect of Irradiation on a Sodium Soap Grease.

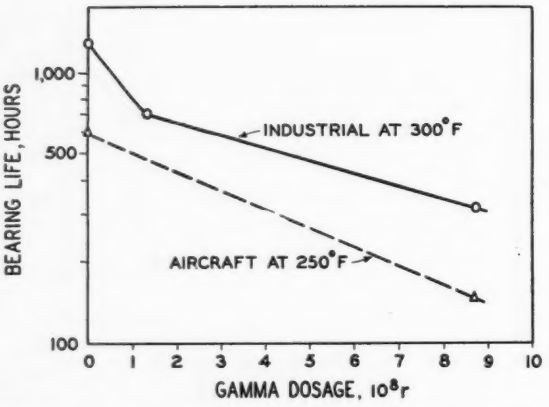


Figure 8. Effect of Irradiation on Bearing Life of Multipurpose Greases.

shown in Figure 8 for the industrial and the aircraft multipurpose greases. After 10^8 *r*, about 55 percent and 80 percent, respectively, of original bearing life was retained.

CONCLUSIONS

This survey of the gamma radiation resistance of some 28 commercial "off-the-shelf" lubricants reveals the following:

1. Several commercial oils and greases can be used in the presence of gamma radiation for dosages of at least 10^8 *r*. Such products will probably provide the basic general purpose lubricants necessary for many of the lubricating requirements in nuclear power plants and accessory equipment.

2. In general, the end effect of radiation on lubricants is similar to severe oxidation. Lubricants darken and acquire an acrid odor; oils show an increase in viscosity; greases show a marked change in their original consistency.

3. The effect of radiation on compounding in lubricants in some cases is more significant in limiting their application than the effect on the bulk material. The release of HCl from chlorinated extreme pressure agents and the breakdown of polymeric viscosity index improvers illustrate this point.

4. The wear properties and load carrying capacity of certain oils are enhanced by irradiation.

5. Gamma irradiation improves the viscosity indexes of petroleum oils.

BIBLIOGRAPHY

1. J. A. Lane, "Where Reactor Development Stands Today," *Nucleonics, 14,* No. 8, 30 (August 1956)
2. R. O. Bolt and J. G. Carroll, "Influence of Nuclear Radiation on Organic Fluids and Lubricants," unpublished, submitted to *Ind. Eng. Chem.*
3. R. E. Lapp and H. L. Andrews, *Nuclear Radiation Physics,* second edition (Prentice-Hall, New York, 1954), p. 127
4. J. Weiss, "Chemical Dosimetry Using Ferrous and Ceric Sulfates," *Nucleonics, 10,* No. 7, 28 (July 1952)
5. C. S. Schoepfle and L. H. Connell, "Effect of Cathode Rays on Hydrocarbon Oils and on Paper," *Ind. Eng. Chem., 21,* 529 (1929)
6. R. Stephenson, *Introduction to Nuclear Engineering* (McGraw-Hill, New York, 1954), p. 169
7. J. G. Carroll and R. O. Bolt, "Effects of Nuclear Radiation on the Oxidation of Lubricants," unpublished, submitted to *Ind. Eng. Chem.*
8. J. G. Carroll, R. O. Bolt, and B. W. Hotten, "Radiation Resistant Greases," *Lubrication Eng., 10,* No. 3, pp. 136-40 (March, 1957)
9. Federal Test Method Standard No. 791, December 15, 1955; Method 331.1

Thermal Conductivity of Aircraft Engine Lubricants at Low Temperatures

The thermal conductivities and thermal diffusivities of a representative aircraft gas turbine lubricant and a representative piston engine lubricant were determined over a temperature range of −100°F. to +80°F. Measurements were made in a spherical apparatus employing a thin film (0.100 inches) of the material under test.

Average results of 0.075 Btu per hr. °F. ft. for the turbine lubricant vs. 0.090 Btu per hr. °F. ft. for the piston lubricant indicate the considerable differences in thermal conducti ity between the materials and the hazard in applying existing empirical relations. The thermal conductivity of the turbine lubricant varied linearly with temperature, while the thermal conductivity of the piston engine lubricant varied irregularly due to wax separaton.

V. E. Schrock & E. S. Starkman
Mechanical Engineering
University of California
Berkeley, Calif.

INTRODUCTION

A consideration of the heating or cooling of a material under either steady state or transient conditions necessitates a knowledge of certain physical properties. The most important of these are thermal conductivity, heat capacity, density and, in cases where there is a phase change, the latent heat. For certain systems it is also convenient to combine thermal conductivity, specific heat, and density into one property called thermal diffusivity.

In attempting to optimize the configuration of an oil transfer system for multi-engined aircraft,* it became clear that the properties mentioned above were either completely lacking in the literature or, if available, were questionable. Of particular concern was the absence of information on hydrocarbon lubricants in the low temperature ranges encountered at altitude or arctic conditions (down to −100°F.).

As a result of this experience, an Air Force sponsored project† was undertaken to provide data for typical aircraft engine lubricants necessary in the design of systems handling these oils at low temperatures.

It was also the purpose to determine if existing pure hydrocarbon or empirical relationships for thermal properties were reliable in the low-temperature region, or if serious error might result from extrapolation of available higher temperature data to the low-temperature region including the solid phase.

To keep the program from becoming too extensive, two representative lubricating oils were chosen for testing. First of these was an aircraft gas turbine lubricant having a viscosity of 10 centistokes at 100° F. and specified[1] by MIL-0-6081A. This material had been examined previously for pumpability characteristics.[2] The other material was a piston engine lubricant specified[3] by MIL-0-6082 and having a viscosity of 80 Saybolt seconds at 210°F. Physical properties are presented to the extent that they are available. Both military specifications have been superseded since the samples were obtained. The properties given in the table below should be useful in determining the applicability of the present data for computations on oils of similar characteristics.

The heat capacity and heat of fusion data for these materials have been presented in a separate paper.[4] The information to be included here concerns thermal conductivity and thermal diffusivity.

THERMAL CONDUCTIVITY

Thermal conductivity, by definition, is the proportionality constant in the equation of the Fourier Law of heat conduction which is:

$$q = -kA\ (dt/dl)$$

where q = heat flow, Btu/hr.; A = area normal to heat flow, ft.^{2}; dt/dl = temperature gradient in the direction of the heat flow, °F./ft.; k = thermal conductivity, Btu/hr. ft. °F. Conductivity is a physical property of matter and, in general, depends upon the state and kind of material.

Physical Properties of Oils Tested

	Turbine Lube MIL-0-6081A, Amend. 1 Grade 1010	Piston Engine Lube MIL-0-6082 Grade 1080*
Color	1 —	——
Appearance	Clear, Transparent	——
Neutralization No.	0.01	——
Precipitation	0	——
Copper Corrosion (3 hr. at 212°F.)	Pass	——
Viscosity:		
CS. at 100°F.	10.316	——
at −40°F.	2810	——
SSU at 100°F.	——	756
at 130°F.	——	329
at 210°F.	——	78.3
Viscosity Index	104	101
Flash, COC, °F.	295	460
Fire, °F.	——	530
Pour Point, °F.	Below −80	5
Gravity, API	29.9	28.5

*AeroShell 80, Shell Oil Co.

This paper was presented at the 3rd Annual ASLE-ASME Lubrication Conference, Atlantic City, October 8-10, 1956.

The magnitude of conductivity depends greatly upon temperature, but pressure is relatively unimportant.

Several theories have been developed for the conductivity (and other transport properties) for liquids based on or extended from the Kinetic Theory of gases, but less success has been achieved than with gases. To apply such theory to petroleum products which are made up of so many molecular species, would be virtually impossible so a discussion of this seems out of place.

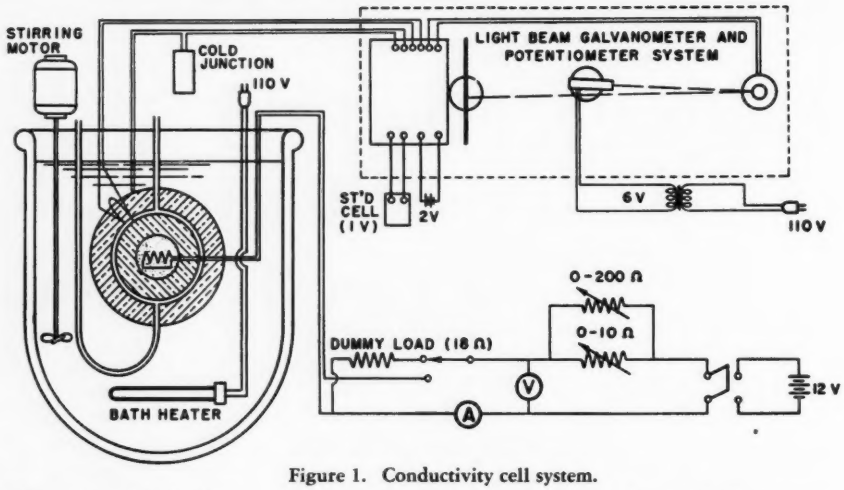


Figure 1. Conductivity cell system.

The thermal conductivity of hydrocarbon lubricating oils has been determined by several investigators[5-9] in the temperature range from ambient to about 400°F. There are no data available in the literature for low temperatures.

In considering measurement of thermal conductivity, there are certain criteria which must be observed for optimum reliability of results. Probably the most important of these is the problem of imposing a temperature gradient on a liquid without creating a convective mode of heat transfer. Other problems are: the possibility of "thermal slip" or an apparent discontinuity of temperature at a liquid-solid interface, heat losses through edges, ends and leads, and instrumentation.

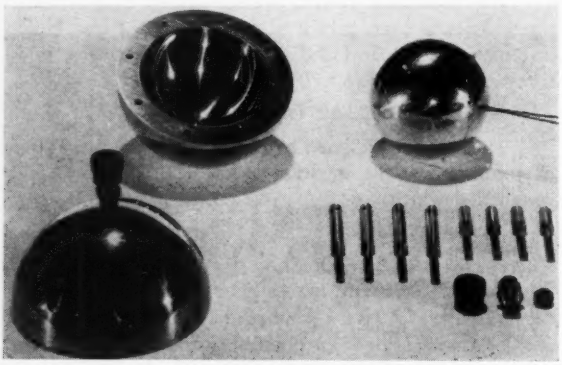


Figure 2. Conductivity cell elements.

All of these problems have been minimized to a varying degree by the investigations reported in the field. Some disagreement exists, however, among those who have done careful measurements of thermal conductivity regarding which of the several methods available is preferable. It is interesting to note that results of several authors, each claiming accuracy of better than one percent, may disagree by 20 or 30 percent.

The experimental determination of thermal conductivity may be classified both as to approach and to apparatus configuration. Steady state, transient heat flow, and ultrasonic velocity techniques are the ones most commonly employed. Steady state results are generally more reliable but also more tedious to obtain than transient heat flow data. Transient methods[10-13] yield thermal diffusivity and, therefore, require an accurate knowledge of heat capacity and density. The additional dependency of these properties on temperature, and a necessity to simplify by assuming them independent of temperature, makes the results by this method questionable in accuracy. The ultrasonic methods suffer from a similar problem of indirection.

The important transient and steady state heat flow methods may employ a number of configurations. These can be classified as thin film or thick film; and flat plate, concentric cylinders, concentric spheres, or hot wires.

The greatest success to date has been achieved using

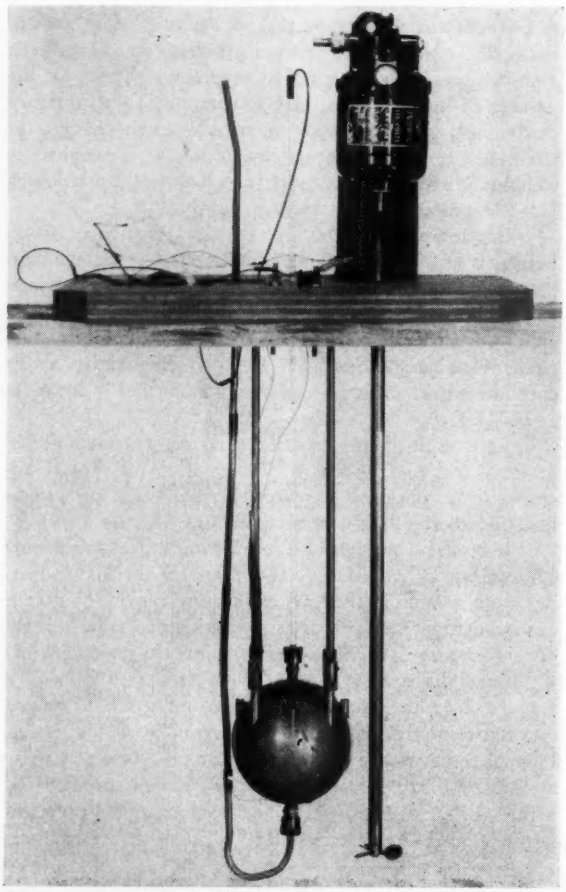


Figure 3. Conductivity cell assembly.

thin liquid films. Apparently this is because the effect of convection is most easily eliminated by such a system. Riedel,[7] Kaye,[9] Ellington,[14] Dick and McCready,[15] to list a few, have used the thin film flat plate apparatus. Smith,[5, 6] Bridgman,[16] and Riedel[17] have used a thin film cylindrical apparatus. Riedel,[18] using thin film spherical apparatus as well as the flat plate and cylindrical systems, found that with careful design and operation the three types will give results which are in excellent agreement. His results are probably the most reliable available. A more complete list of references, together with an evaluation of reliability, is presented by Sakiadis and Coates[19] in an excellent survey of the literature covering the period 1923 to 1952.

Bates[20] has used a thick film flat plate apparatus. The liquid layer (approximately 5 inches thick) was heated from above so that the density gradient would not create fluid movement. A temperature difference of about 80°F. was imposed on the liquid layer. Edge effects would appear to be large in this case, and it is likely that convection was present to some degree.

Ellington[14] contends that no previous investigator has offered definite proof the system used was one of pure conduction, and this point is well taken. Most authors have considered the problem of convection in the design of the equipment and selection of operating conditions. They fail to demonstrate experimentally, however, that the equipment as used is free from convection.

Schmidt and Milverton,[21] and Schmidt and Saunders,[22] have determined experimentally the point of instability in a fluid heated from below, and correlate their findings with theory of Rayleigh,[23] Jeffreys,[24] and Low.[25] The basic information in these papers, while useful in selecting conditions of operation, would not apply directly to more complex geometries.

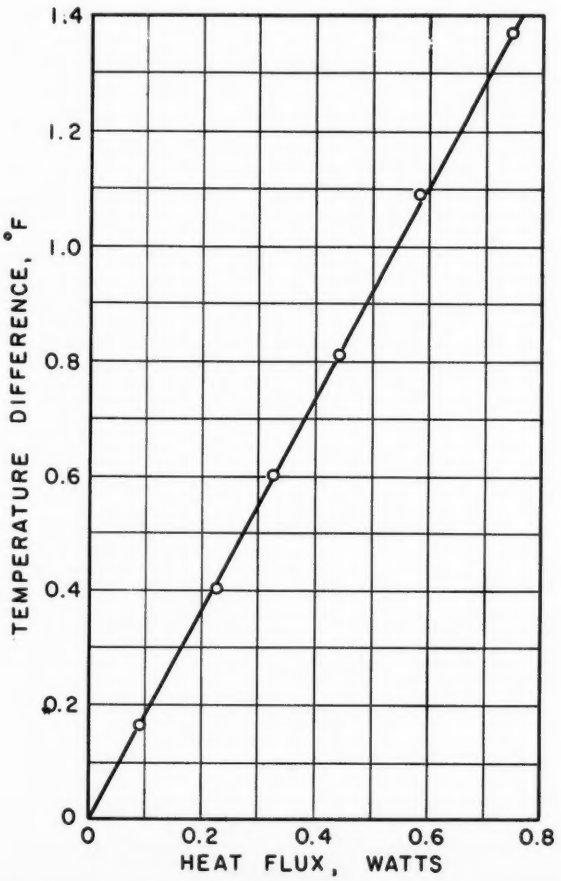


Figure 4. Typical temperature difference vs. heat flux.

To demonstrate for each apparatus that pure conduction exists, Ellington proposed that heat flux be plotted as a function of the temperature difference. Then, for pure conduction a straight line should result which passes through the origin. Ellington's data plotted as a straight line, but the line did not intercept the origin. The slope of the linear portion of the line was then used in the calculation of the conductivity because a value of conductivity computed from any single point on the line would be erroneous. The translation was explained as arising from some environmental difference between the liquid-filled cell during tests and the evacuated cell during calibration. Ellington feels that such an effect, together with convection, is the cause of disagreement among data in the literature.

Although Ellington's work was done at low temperature, the materials were liquefied petroleum gases and, therefore, cannot be used for direct comparison with the present results.

Available Empirical Relationships

A number of empirical equations are available for *liquids*. Some require knowledge of viscosity, molecular weight, specific heat, and temperature. Considering the inaccuracies which are likely to exist in these quantities alone, the values computed from such normally complex relationships would be subject to question.

A simple, more direct relationship was presented in 1929 by Cragoe.[26] It involves only temperature and the density of the oil, and is:

$$k = 1 - 0.003\ (t\text{-}32)\frac{0.813}{Sp.\ Gr.}$$

in which k = Btu/hr. ft. °F.; t = Temp., °F.; *Sp. Gr.* = Specific Gravity, 60°F./60°F. While such a simple equation cannot be extremely accurate for all oils, it could be useful in many computations in the normal temperature range.

Experimental Apparatus

Because of the reasons outlined above, a thin film spherical apparatus was decided upon. It seemed to be free from some of the uncertainties inherent in flat plate or cylindrical apparatus, primarily involving correcting for end losses. Since there are no ends to spherical apparatus, the only distortion of the presumed radial heat flow that may exist is caused by heater and thermocouple wires and by spacers. These effects can be kept small by using very fine wires, and by using spacers of material equal in conductivity to the sample. Thermal slip probably is not a factor in these tests since the materials all exhibited no reluctance to wet metallic surfaces. If this phenomenon were present at all, it is believed the effect would be minor.

The system is shown diagrammatically in Figure 1, and in photographs in Figures 2 and 3. The two spheres shown were machined in halves and placed together with copper machine screws to form spherical shells. A liquid film is held between the concentric copper spheres, the sample thickness being nominally 0.100 inches.

Before assembling the apparatus, the surfaces were

plated with gold to resist corrosion and then were measured to 0.0001 inch. The maximum variation in any radial dimension was found to be 0.0007 in., but the parts were placed together in such a way that the thickness of the sample does not vary as much as 0.0005 in. This figure is considered to be the accuracy of the sample thickness (½ percent).

As a heat source, 30-gauge nichrome wire was wrapped around a bakelite core contained within the inner copper sphere. The nichrome resistance wire was securely fastened using an insulating cement. A spiral groove cut on the bakelite sphere and containing the wire was designed to give radially symmetrical heat distribution. For ease of assembly, the lead wires to the heater were passed through small teflon sleeves mounted in holes through the copper spheres at the split.

In order to hold the inner sphere concentric within the outer, it was necessary to use six plastic spacers, cylindrical in shape and 0.05 in. in diameter. These were threaded and screwed into the inner sphere. Accurate adjustment of the length of each spacer was accomplished to within 0.0001 inch of the mean sample thickness as described above.

Several materials were considered for use as spacers, the one finally selected being a plastic which is sold under the trade name of Kel-f, (polychlortrifluoroethylene). This plastic has an unusually high modulus of elasticity, 200,000 psi, is resistant to virtually all solvents, and has a thermal conductivity of the same order of magnitude as the oils tested. These features made Kel-f an ideal material, since the spacers would be of sufficient strength and yet would not distort the isotherms within the sample being tested.

The temperature drop through the test sample was measured by embedding select, teflon coated, 40-gauge B & S wire differential copper constant thermocouples in the surfaces of the two spheres. About eight inches of constantan wire was left in the sample between the junctions to insure that serious error would not result from heat conduction through that wire. The thermocouples were very carefully calibrated (see Reference 4). Each differential couple was carefully checked for zero reading under isothermal conditions throughout the range of absolute temperatures encountered in the study.

To determine the temperature of the material at which the test was conducted, it was necessary to fit an additional thermocouple to the outside of the outer sphere. This was also used as an indication of the temperature of the bath. The control procedure was employed as described in Reference 4. The maintenance of a constant bath temperature was critical, because the accuracy of results greatly depends upon a condition of steady state conduction.. As a result, it was necessary for the operator to exercise greater care (than in the case of specific heat measurements) in maintaining the bath temperature constant. The maximum deviation of points from the mean line in the plots typified by Figure 4 would indicate a maximum variation of the bath temperature of 0.025°F. with the average being considerably better.

A copper tube was used for filling the apparatus, and a glass tube used to allow observation of the liquid level. For this purpose, two holes were drilled (No. 44 drill, 0.086 in.) through the outer sphere on the axis perpendicular to the split, and two sealastic fittings mounted in the sphere at these locations.

The apparatus was suspended from a wooden lid and immersed in a methanol bath. External equipment such as power source, potentiometer, galvanometer, etc. were used as shown in Figure 1.

Experimental Procedure

To prepare the apparatus for a test, it was first flushed with carbontetrachloride several times, drained and air dried. The test sample was then warmed and introduced into the apparatus using a 100 cc hypodermic syringe to inject the material into the copper filling tube. After the initial filling, the apparatus was allowed to stand overnight and additional sample material was passed through in order to wash out any bubbles that may have become trapped.

Determination of a single thermal conductivity value was made by establishing steady state within the apparatus for a series of heat rates at a particular temperature level. The purpose of utilizing multiple heat rates was to prove that pure conduction existed, and to obtain greater accuracy than would be obtainable by the single point method. Thermal conductivity was then computed from the plot of temperature difference vs. heat flux. Each point on the curve required steady state within the limit of constancy of the bath temperature, and necessitated an average of one hour to establish. With each change of heat rate, the bath temperature was adjusted about half the anticipated change in temperature difference. This procedure served two

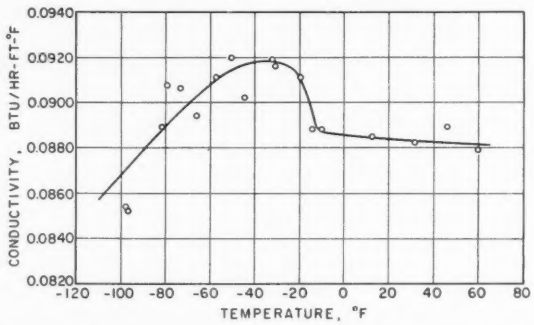


Figure 6. Thermal conductivity of piston engine lubricant.

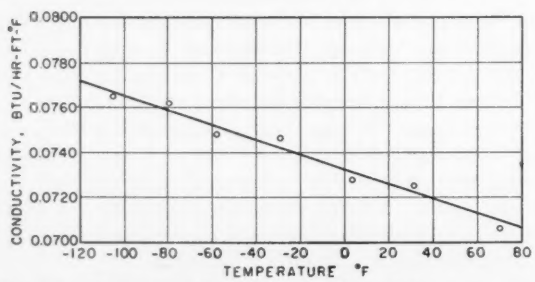


Figure 5. Thermal conductivity of turbine lubricant.

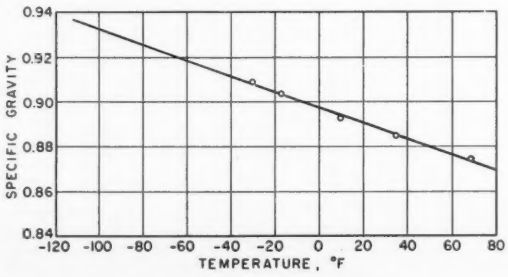


Figure 7. Specific gravity of turbine lubricant.

functions: it reduced the time required for steady state, and it kept the mean temperature a constant.

Discussion of Results

The system and procedures employed in this investigation are believed to be as suitable for the determination of thermal conductivity as any used previously. A greater accuracy could have been achieved by improved instrument precision, but the expense was not considered justified. Attendant to more precision would also be an increased cost due, in part, to the need for a more constant bath temperature.

That pure conduction existed was clearly shown by the plots of temperature difference as a function of heat rate (see Figure 4). In all cases, the curves intersected the origin of the coordinates and, therefore, the effect found by Ellington was not confirmed by these tests. Some thermoelectric potentials in lead wires at locations not within the isothermal environment in the early phases of the research, led to a belief that such an effect was present. This was later determined to have been caused by a differential thermocouple which did not read zero under isothermal conditions. Perhaps a similar phenomenon caused the translation of Ellington's data.

The capabilities of the cell were demonstrated by collecting data for materials for which the data have already been well established by many observers. These materials included toluene and water. Toluene was selected because it is a hydrocarbon having a conductivity in the same range as the oils to be tested, and the water because no other material has been tested more thoroughly. The toluene results were compared with data of Smith,[5] Bridgman,[16] Riedel,[18] and Abas-Zade.[27] The present data were seen to agree most closely with those of Riedel, although the temperature coefficient was found to be a somewhat greater negative value. Riedel, incidentally, reports excellent agreement between results for toluene using three different apparatus. Data of Abas-Zade are about 13 percent higher than the present data but have the same temperature coefficient. This difference cannot be considered disagreement, since his tests were conducted at critical pressure rather than atmospheric, which would have the effect of increasing the conductivity.

Water data were compared with those of Smith,[5] Riedel,[8] and Timrot.[28] The agreement with Riedel and Smith compared within 1.5 percent from 32 to 100°F. Timrot's results are higher at 32°F., but agree at 100°F.

The results of the tests made on the turbine lubricant, MIL-0-6081A, grade 1010, are presented in Figure 5, and are seen to vary linearly with temperature. The slight crystallization which occurred in the 1010, as evidenced in specific heat data, had no effect, within the precision of these measurements, upon the thermal conductivity. The thermal conductivity of the oil varied linearly from 0.077 to 0.071 Btu per hour ft. °F in the range of —120°F. to +80°F.

Results for the piston engine lubricant MIL-0-6082, grade 1080 oil are shown in Figure 6. Unlike the turbine oil, a noticeable change in conductivity takes place with the partial crystallization. The liquid has a slight negative temperature coefficient, while the solid displays a positive temperature coefficient.

The empirical equation of Cragoe predicts a conductivity somewhat above that of the turbine oil and somewhat below the 1080 grade oil, being in better agreement with the turbine oil. Since the conductivities of those oils differ by 25 percent at 60°F., evidently the equation would be suitable only for rough computations.

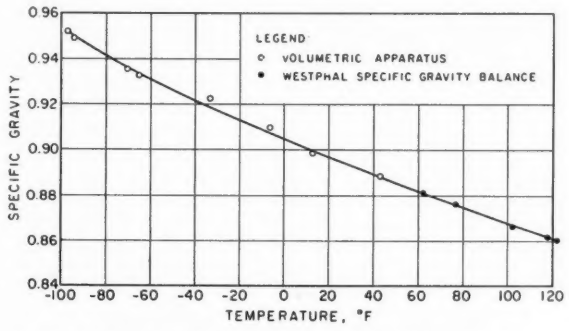


Figure 8. Specific gravity of piston engine lubricant.

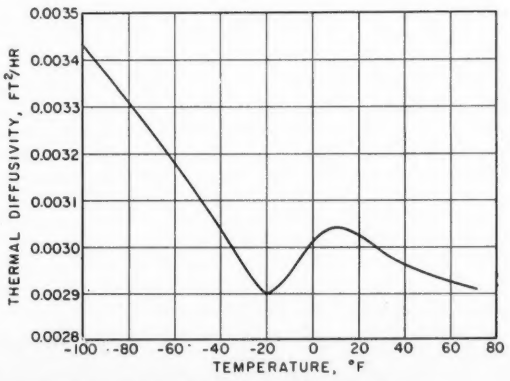


Figure 9. Thermal diffusivity of turbine lubricant.

Conclusions

(1) The turbine oil had a linear variation of conductivity with temperature in the range tested with no apparent effect due to the slight crystallization at the cloud point. The piston engine lube, in contrast, experiences a noticeable change on freezing, and has a positive temperature coefficient in the solid phase and a negative one in the liquid phase.

(2) Existing empirical equations are inadequate for lubricants of the types tested, particularly in the temperature region covered in this investigation.

(3) The spherical apparatus designed for the purpose of this investigation, together with the procedure followed, comprise features which yielded reliable results. An analysis of instrument error predicted a probable error in the thermal conductivity (point values) of 1.68% which is

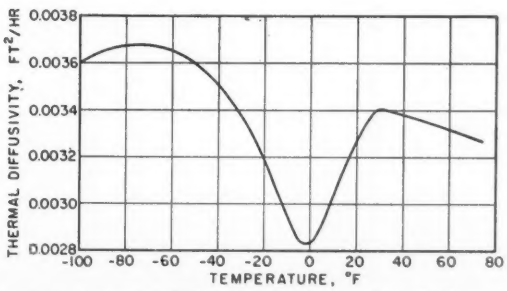


Figure 10. Thermal diffusivity of piston engine lubricant.

a little greater than the average deviation of points from the mean line drawn. Allowing for possible fixed error, the results are believed within 2% of the absolute values.

Thermal diffusivity, while a physical property of matter, is defined by the grouping of the properties thermal conductivity, density, and specific heat as follows:

$$\alpha = k/\rho c$$

where α = thermal diffusivity, ft.^{2}/hr.; k = thermal conductivity, Btu/hr. ft. °F.; ρ = density· lb./ft.^{3}; c = specific heat, Btu/lb. °F.

Direct measurement of the thermal diffusivity is possible using a transient conduction system and, as mentioned previously, the measurement of diffusivity is sometimes used as a means of obtaining thermal conductivity data. It is more common, however, to obtain diffusivity from the other measured properties and, in the basic objective of this research program, the determination of heat capacity data was included. The thermal diffusivity was computed from the available data plus measurements of density.

The measurement of the density of a hydrocarbon in the liquid state is a relatively simple procedure for which a number of apparatus are available. The Westphal specific gravity balance was selected to be used for this part of the investigation because of its accuracy and simplicity.

To obtain low-temperature and solid state data for the 1080 grade oil, an apparatus was constructed of readily available materials. A cylindrical bottle having a volume of 260 cc was fitted with a two-hole rubber stopper and a glass tube and thermometer. The tube was calibrated using methyl alcohol and found to have a uniform volume of 0.428 cc/inch. A dry ice cooled methanol bath was used to regulate the temperature of the apparatus.

A preliminary test was made with the apparatus filled with methanol. The thermal expansion, measured over the temperature range —100°F. to ambient, was in agreement with data given in Lange, Handbook of Chemistry.

Next the bottle was partly filled (232 cc) with sample, the level being within the constant cross section of the bottle. The remaining space was filled with methanol, which is immiscible with the oil, and data collected from the lowest temperature at which the Westphal balance had been used to a temperature of —100°F.

Density of the two lubricating oils, MIL-0-6081A grade 1010, and MIL-0-6082 grade 1080, were obtained as described in the previous section, and are presented in Figure 7 and 8, respectively. Data obtained for the 1080 grade oil by the two methods appear in agreement.

Thermal diffusivity was computed from the specific heat, thermal conductivity and density, and the results for the two oils are given in Figures 9 and 10. Computations were made from faired curves. These data vary rather irregularly, due primarily to the effect of the specific heat.

In view of the accuracy of the other measurements, the accuracy appears to be about 2% for thermal diffusivity.

CONCLUSIONS

(1) Thermal diffusivity of the two oils tested varies irregularly in the low-temperature region (ambient to —100°F.). Increased specific heat in the region of partial crystallization is the primary cause of the irregular variation of this property.

(2) The densities of the two aircraft engine lubricants appeared to be a linear function of temperature. Westphal balance and displacement bottle methods proved reliable. Accuracy of these data is approximately 0.2%.

BIBLIOGRAPHY

1. "Military Specification Lubricating Oil, Jet Engine," MIL-0-6081A, Amend. 1, U.S. War Dept., Washington, D.C., Dec. 21, 1951.
2. "Military Specification Lubricating Oil, Aircraft Reciprocating Engines," MIL-0-6082, U.S. War Dept., Washington, D.C., Mar. 30, 1950.
3. Starkman, E. S., & J. H. Bridges, "Pumpability of Aircraft Turbine Lubricants at Low Temperatures," *Lubrication Engineering, Vol. 12,* 1956, p. 43.
4. Schrock, V. E., & R. E. Gott, "Specific Heats of Aircraft Engine Lubricants at Low Temperatures," *Lubrication Engineering, Vol. 13,* 1957, p. —.
5. Smith, J. F. D., "The Thermal Conductivity of Liquids," *Trans. Amer. Soc. Mech. Eng., Vol. 58,* 1936, p. 719.
6. Smith, J. F. D., "Thermal Conductivity of Liquids," *Ind. Eng. Chem., Vol. 22,* 1930, p. 1246.
7. Riedel, L., "Thermal Conductivity of Liquids," *Mitt. Kaltestech. Inst. Karlsruhe,* No. 2, 1937, 45 pp.
8. Riedel, L., *Chem. Ing. Tech., Vol. 23,* 1951, p. 465.
9. Kaye, G. W. C., & W. F. Higgins, *Proc Roy. Soc. (London), Vol. A117,* 1927-28, p. 459, and *Vol. A122,* 1929, p. 623.
10. Shiba, H., "The Isothermal & Adiabatic Compressibilities, the Specific Heat & Heat Conductivity of Liquids," *Inst. of Phys. Chem. Res. Tokyo, Vol. 16,* 1931, p. 205.
11. VanDerHeld, E. F. M., & F. G. VanDrunen, "A Method of Measuring the Thermal Conductivity of Liquids," *Physica, Vol. 15,* 1949, p. 865.
12. Soonalawa, M. F., "Thermal Conductivity of Water," *Indian Journal of Physics, Vol. 18,* 1944, p. 71.
13. Sakiadis, B. L., & J. Coates, Louisiana State Univ. Eng. Exp. Sta. Bul. No. 46, 1954.
14. Ellington, R. T., Jr., "Thermal Conductivities of Liquid Hydrocarbons at Low Temperatures," Ph.D. Thesis, Illinois Inst. of Tech., 1953.
15. Dick, M. T., & D. W. McCready, "Thermal Conductivity of Liquids," presented at ASME Annual Meeting, Dec., 1953, Preprint No. 53-A-187.
16. Bridgman, P. W., "The Thermal Conductivity of Liquids Under Pressure," *Am. Acad. of Arts & Sci.. Vol. 49,* 1923, p. 141.
17. Riedel, L., "The Determination of the Thermal Conductivity & the Specific Heat of Various Mineral Oils," *Chem. Ing. Tech., Vol. 22,* 1950, p. 107.
18. Riedel, L., "New Thermal Conductivity Measurements for Organic Liquids," *Chem. Ing. Tech., Vol. 23,* 1951, p. 321.
19. Sakiadis, B. C., & J. Coates, Louisiana State Univ. Eng. Exp. Sta. Bul. No. 34, 1952.
20. Bates, K. O., "Thermal Conductivity of Liquids," *Ind. Eng. Chem., Vol. 25,* 1931, p. 431.
21. Schmidt & Milverton, *Proc. Roy. Soc., Vol. A1952,* 1935, p. 586.
22. Schmidt & Saunders, *Proc. Roy. Soc., Vol. A165,* 1938, p. 216.
23. Rayleigh, *Phil. Mag., Vol. 32,* 1916, p. 529.
24. Jeffreys, H., *Proc. Roy. Soc., Vol. A118,* 1928, p. 195.
25. Low, A. R., *Proc. Roy. Soc., Vol. A125,* 1929, p. 180.
26. Cragoe, C. S., "Thermal Properties of Petroleum Products," U.S. Bur. of Standards Misc. Pub. No. 97, 1929.
27. Abas-Zade, A. K., "Measurement of the Heat of Conductivity of Liquids . . .," *Doklady, Akad. Nauk Azaebaidzhan, USSR 3, No. 1,* 1947, p. 3.
28. Timrot, D. L., "Heat Conductivity of Water at High Temperatures," *J. Tech. Phys. (USSR), Vol. 10,* 1940, p. 1063.

ACKNOWLEDGEMENTS. The services of Mr. Masamichi Watanabe, Mr. Raymond Gott, and Mr. John Mark were invaluable in this research. Mr. Charles Beeson supervised the extremely difficult task of accurately machining the copper spheres used in the conductivity apparatus. Lubricants were supplied by Shell Development Co. and the California Research Corp.

*"All Weather Oil-Transfer System for Multi-Engined Aircraft," Contract AF 18 (600)-3.

†"Thermal Properties of Aircraft Engine Lubricants at Low Temperature," Contract AF 33(616)-2116.

Editor's Note: Comments of H. A. Hartung on the related paper "Specific Heats of Aircraft Engine Lubricants at Low Temperatures," by V. E. Schrock & R. E. Gott, published in the June '57 issue of *Lubrication Engineering,* are also pertinent to this paper.

Transition Temperature for Surface Damage in Sliding Metallic Contact

L. F. Coffin, Jr.
General Electric Research Laboratory
P. O. Box 1088
Schenectady, N. Y.

It has been observed that in inert gaseous atmospheres, repetitive sliding of non-alloying metallic couples produces low friction, smooth and relatively low rider contact area, and a narrow, smooth wear track on the mating disk. Alloying couples, on the other hand, lead to high friction and large and abraded contact surface on the rider and disk. These two modes of sliding were defined as sliding by shear, and sliding by welding.

The present paper considers the effect of both liquid atmosphere and temperature on alloying couples, particularly copper-copper, copper-nickel, and nickel-nickel under repetitive sliding. A transition temperature is observed for the various liquids tested, below which sliding by shear is observed, and above which sliding by welding takes place. The transition is very sharp with temperature, and the sliding conditions are found to be reversible as the temperature is raised or lowered through the critical range. The effect of speed of sliding, load, kind of fluid, and kind of metal on the transition temperature are investigated and a mechanism proposed, based on surface diffusion effects.

INTRODUCTION

The interaction between mating metals in sliding contact has undergone serious study in recent years. This can be attributed largely to the interest, on the part of designers, in applications where new materials are encountered, or where conventional methods of lubrication cannot be used. This is particularly true in nuclear reactors. Here parts are required to undergo sliding in such unusual media as high-temperature sodium or high-temperature, high-pressure water. Under these conditions, conventional bearing materials are generally unacceptable because of their poor corrosion resistance, and the basis for selection of materials is generally dependent on factors other than that of outstanding bearing performance.

The importance of adhesion as a major cause of friction between sliding solids has been well established by Bowden and co-workers.[1, 2] In their interpretation of metallic friction, local adhesion and cold welding occur between mating asperities on sliding surfaces regardless of applied load or speed of sliding. The behavior has been shown to be particularly pronounced when the mating surfaces have been carefully cleaned and outgassed in high vacuum.[3, 4] On the other hand, there has been experimental evidence which would indicate that the cold welding theory for friction is not completely satisfactory. This is based principally on the sliding behavior of certain metallic couples. Ernst and Merchant[5] have proposed that metallic couples which exhibit negligible solid solubility generally have anti-scoring properties (and hence greater resistance to cold welding). Roach, Goodzeit and Totta[6] have investigated the sliding characteristics of many metals against steel and concluded that good bearing metals were those which had limited solid solubility for steel at their melting points. Machlin and Yankee,[7] in a study of sliding of metals on freshly cut surfaces, propose that the degree of solid phase weldability is governed by the comparative ratio of the work of adhesion and the strength of the weaker component. Recently, the author published results of experiments[8] in which the alloying or non-alloying of mating couples correlated well with sliding with or without damage by welding, and in addition gave evidence to show the importance of environment on the sliding behavior of metallic couples.

The work of the author, as well as others mentioned above, indicates that under dry conditions there appears to be at least two distinct modes of metallic sliding. In one case, adhesion between sliding surfaces is quite pronounced, cold welding takes place, the coefficient of friction is high, and metal transfer and surface damage is severe. In the other cases, adhesion is weak, there is an absence of cold welding, the coefficient of friction is low, and metal transfer and surface damage light, or at least relatively low. This is best seen by a comparison of the contact areas of sliders of various metals seen run in sliding contact against other metals under various conditions such as shown in Figure 1. Three facts are brought out in this figure:

(1) That damage in couples such as copper vs. nickel (which form a continuous series of alloys) are severe regardless of the gaseous environment as shown in Figure 1(a) and (b).

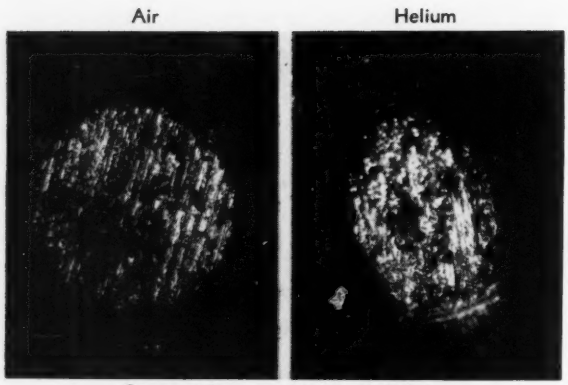
(2) That some non-alloying couples such as cadmium vs. iron may act very differently depending on the gaseous environment, Figure 1(c) and (d).

(3) That other non-alloying couples are insensitive to the gaseous environment and slide without welding regardless of the atmosphere, Figure 1(e) and (f). These experiments have been reported in more detail elsewhere.[8]

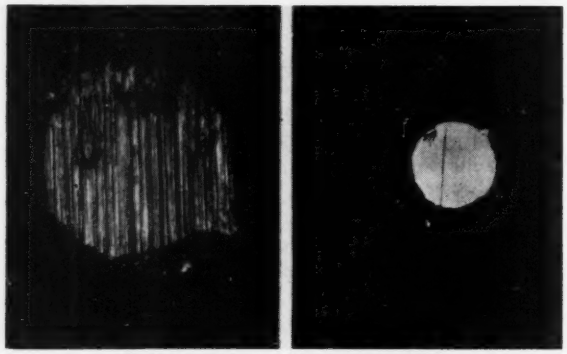
The present investigation is directed toward that class

L. F. Coffin

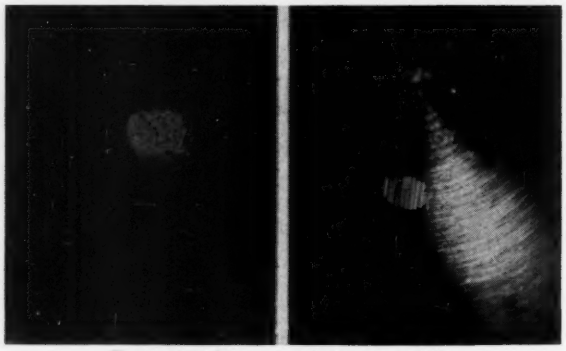
This paper was presented at the ASLE 11th Annual Meeting, Pittsburgh, April 6, 1956.



Copper rider run against nickel disk.
(a) $\mu = 1.00$ after 100 turns. (b) $\mu = 5.25$ after 100 turns.



Cadmium rider run against iron disk.
(c) $\mu = 1.45$ after 100 turns. (d) $\mu = 0.39$ after 100 turns.



Tungsten rider run against copper disk.
(e) $\mu = 0.32$ after 100 turns. (f) $\mu = 0.60$ after 100 turns.

Figure 1. Comparison of area of riders after contact with various metal discs.

of mating couples which is completely soluble in each other and, according to their phase diagram, form a single-phase alloy regardless of composition. For this class of metallic couples, it is desirable to know whether there are conditions which permit the sliding characteristics to change from the type where severe surface damage occurs as indicated in Figure 1(a), to the second type as indicated in Figure 1(f). Previous experience has shown that, at room temperature and with a gaseous atmosphere, welding invariably occurs during sliding. On the other hand there may be conditions where, because of the normal load, speed of sliding, temperature, or environment, the mode of sliding might change. A study of these changes would then yield some worthwhile information as to the nature of adhesion in the sliding process.

APPARATUS

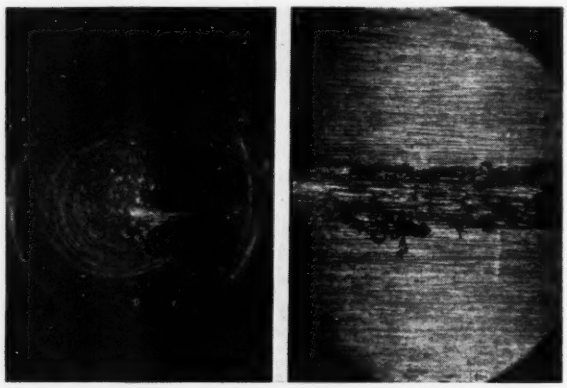
For all the tests reported here, the disk and rider apparatus illustrated and described in more detail earlier[8] was used. Briefly, the apparatus permits the continuous measurement of the frictional force of a small hemispherical rider ¼" in diameter, against the rim of a slowly rotating 2¼" diameter disk. Environment and temperature can be controlled over a wide range of conditions. For more details, the reader is referred to the earlier paper.

EXPERIMENTAL RESULTS

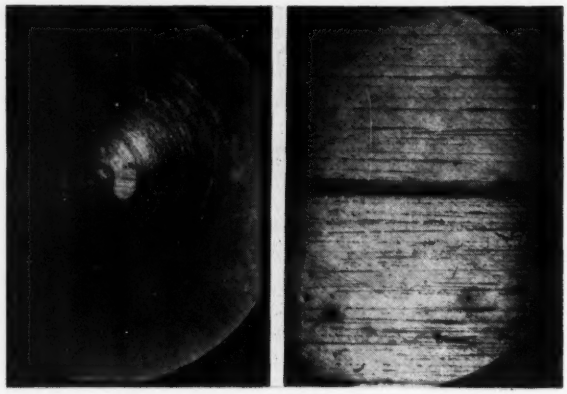
The experiments reported in the present paper were carried out on couples of like materials or couples which could form complete solid solutions. In some experiments the couple selected was a nickel rider against a copper disk; in others, both mating members were copper; while in still others, the mating metals were both nickel. In all cases, whether one follows the alloying rule or the work-of-adhesion criterion, solid-phase welding is strongly indicated.

Gaseous vs. Liquid Environment at Low Temperature

If a difference in the strength of the welded asperity were to occur, it would appear logical that temperature would play a very important role. Consequently, experiments were first performed on the nickel-copper couple in helium, in which the temperature was reduced to —150° C. and sliding permitted for some 60 revolutions. As seen in



After 60 revolutions in helium at –160° C.



After 60 revolutions in liquid nitrogen at –195° C.

Figure 2. Surface damage of copper disc and nickel rider. (20X)

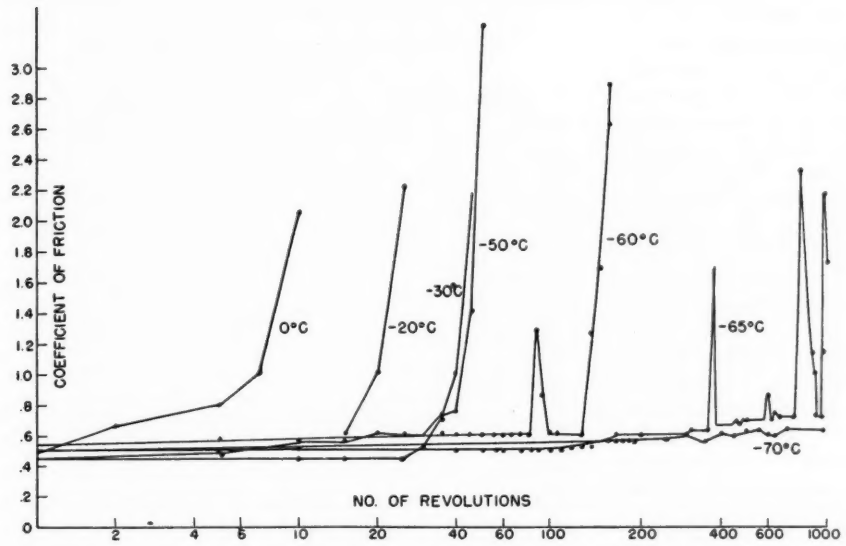


Figure 3. Effect of temperature on revolutions for damage of copper-copper couple.

Figure 2, welding has produced severe surface damage and has resulted in a rise in coefficient of friction to 1.44. On the other hand, a similar couple when immersed and run in liquid nitrogen was found to undergo little surface damage, a markedly reduced area of contact on the rider, and a substantially lower friction coefficient, 0.87. This is seen in Figure 2(b). The substantially different contact areas on the riders (and, correspondingly, the wear track on the mating disks) indicates that two distinct modes of sliding exist here. There are two possible explanations for the difference in sliding behavior: (1) the pronounced difference in thermal characteristics of the gaseous and liquid media produces a substantial difference in interface temperature during sliding and, consequently, a difference in adhesion; or (2) the liquid nitrogen is affording boundary lubrication. In either case, it seemed desirable to carry out the same tests in a liquid whose temperature could be varied over wide ranges.

Copper vs. Copper in Ethyl Alcohol

For these experiments, the couple copper vs. copper was selected for study. The disks were carefully polished to a surface roughness of 2-6 micro-inches RMS and cleaned to remove grease and other contaminants. A predetermined normal load of 470 gms. was applied, and the disk was rotated at a fixed speed giving a velocity of 21″/min. Absolute ethyl alcohol was used as the environment because of its low freezing point.

For each disk and rider tested, a temperature was selected and held and the coefficient of friction obtained as a function of revolutions. At room temperature, the friction coefficient was found to increase almost immediately, while at lower temperatures there was a delay time prior to the sharp increase in friction. Figure 3 shows the behavior for the various test temperatures. For example, with the temperature —50° C., some 40 revolutions were required to cause an abrupt rise in friction; while at —60° C., the required revolutions increased to 120. At —65° C., a curious behavior was noted where the friction increased sharply several times and then recovered. At —70° C., some 1000 revolutions produced no noticeable increase in friction during the entire test.

For a particular temperature, the marked rise in friction coefficient indicates a sudden seizure and damage to the sliding surfaces. Prior to this, the sliding surfaces can be considered to be deformed only by a shear deformation, without welding. The difference can be clearly seen by a visual examination of the wear track and contact area, Figure 4. When the temperature is sufficiently low, there is no evidence of seizure in the wear track and contact area. This is similar to the non-alloying couples as typified by Figure 1(d), (e), and (f). For a slightly higher temperature, the wear track and contact area are abraded and give distinct evidence of seizure and galling. This type of surface damage is similar to that found in the alloying-type couples, Figure 1(a), (b), and (c).

From these investigations it appears that a critical temperature exists below which, for a particular surrounding atmosphere, the two surfaces can be rubbed together without damage, as manifested by lack of seizure, galling, or high friction. For the conditions of the experiments described here, this temperature appears to be almost —70° C.

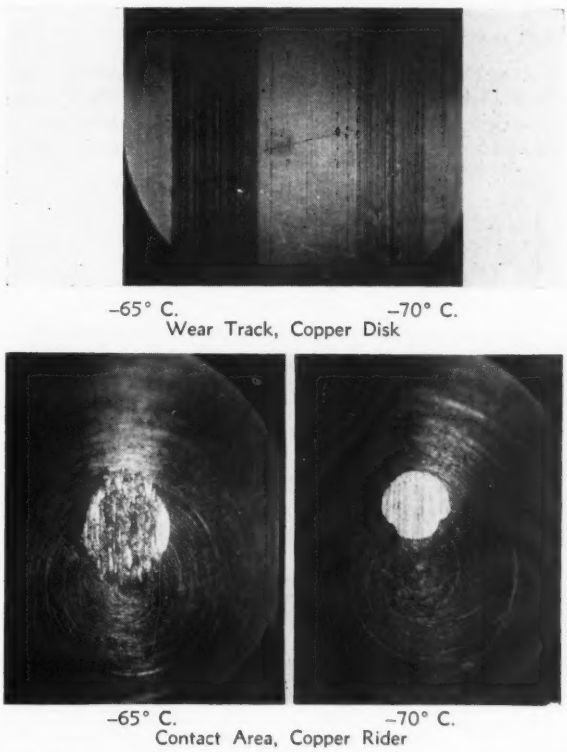


Figure 4. Damage in copper-copper couple following 1000 revolutions in absolute ethyl alcohol.

The curious behavior of the run made at —65° C. (as shown in Figure 3) is of particular interest, since it suggests the possibility that the surface can be damaged, then repairs itself, then is redamaged. To investigate this further, an experiment was performed on the copper-copper couple in which the temperature was changed during the course of the test. The results are shown in Figure 5, where the friction coefficient and test temperature are plotted as a function of the number of revolutions. The couple is first damaged by running for several revolutions at room temperature, and the temperature of the ethyl alcohol decreased to —80° C. As seen in Figure 5, the friction coefficient gradually decreases until after 100 revolutions a value of 0.48 is reached, indicating that a change in sliding characteristics has occurred. At this point the temperature was gradually raised. The friction coefficient remained constant until a temperature of —65° C. was reached, at which point it rose abruptly. By decreasing the temperature to —80° C., the friction coefficient recovered and fell to a value of about 0.4. The temperature was again increased until at about —56° C. seizure occurred. The process of recovery by reducing the temperature, and seizure by increasing the temperature, was a repetitive one. It was observed, however, that the temperature necessary for the sharp increase in friction generally rose with successive repetitions of the temperature cycle.

The temperature at which the sliding characteristics of the copper-copper couple in ethyl alcohol change so abruptly is referred to in this paper as the "transition temperature." Below the transition temperature, sliding apparently takes place by shearing in that cold welding is absent; while above this temperature, cold welding, surface damage, and high friction appear.

Effect of Sliding Velocity on the Transition Temperature of the Copper vs. Copper Couple

Having established that the transition temperature was sharply defined and fairly reproducible for the copper-copper couple, the effect of sliding velocity was investigated. It could be argued that the change in sliding characteristics is due merely to the initiation of local boiling at the interface, and the presence of the vapor phase permits higher contact temperatures and a greater welding tendency. By increasing the sliding velocity, the tendency toward vaporization would occur more readily, and the transition temperature would then decrease. To support or reject this hypothesis, tests were made on a copper-copper couple in ethyl alcohol and other fluids. The procedure was to lower the temperature to —80° C., slide at this temperature for several revolutions at a particular velocity, then gradually increase the temperature while maintaining the velocity constant, until a transition in sliding takes place. The test was then stopped, the temperature lowered to —80° C., and sliding again permitted at a substantially different velocity. Again after several revolutions at —80° C. the temperature was raised, and the new transition temperature noted. The process was repeated several times, while the sliding velocity was alternated between a high and a low value.

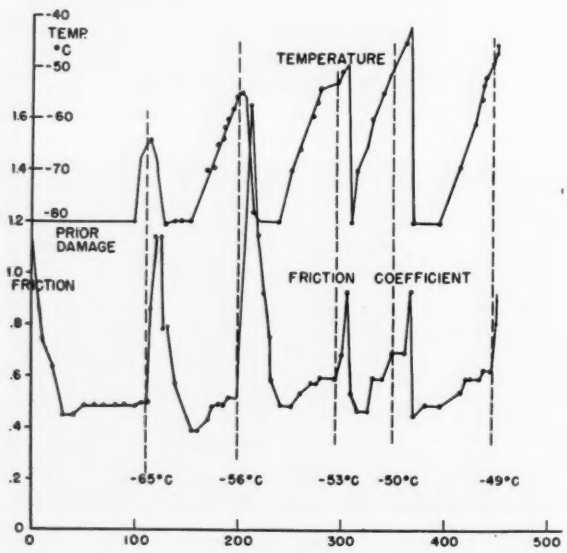


Figure 5. Effect of temperature on damage and repair of the copper-copper couple during sliding.

Table I

Effect of Sliding Velocity on Transition Temperature Copper vs. Copper

Ethyl Alcohol		Acetone	
Velocity	Temp., °C.	Velocity	Temp., °C.
High	−47	High	−15
Low	−50	High	−18
High	−3*	High	−4
Low	−33	Low	−40
High	−17	High	−10
		Low	−32
Hexane		**Paraffin**	
High	−7	High	+34
Low	−21	Low	+11
High	−8		
Butyl Alcohol			
High	−15		
Low	−60		
High	−39		
Low	−47		

Key: High Velocity = 21 in./min.; Low Velocity = 3 in./min.; *Subsequent to a 64-hour delay.

Results of the experiment are shown in Table I for various liquid baths. It is immediately apparent that two rather distinct transition temperatures exist, one for each sliding velocity. Although the transition temperatures are not completely reproducible, the transition appears in each case as the test progresses, the higher velocity giving the higher transition temperature. Thus, the behavior is in direct opposition to the vaporization hypothesis, and one is forced to conclude that the effect is not due to local boiling.

Effect of Normal Load on Transition Temperature of Copper-Copper in Ethyl Alcohol

According to Bowden, increasing the normal load merely increases the number of mating asperities, but does not affect appreciably the local contact pressure borne by any one pair of asperities in contact, since they undergo plastic deformation. This hypothesis assumes that strain hardening is negligible. In the present experiments, one would not expect an increase in normal load to affect the transition temperature, since the local contact pressures are not changed appreciably.

To investigate this point, the copper-copper couple was again tested in ethyl alcohol. The same procedure was

Table II

Effect of Normal Load on the Transition Temperature
Copper vs. Copper in Ethyl Alcohol, 21 in./min.

Load, Grams	Transition Temperature, °C
465	−46
373	−51
280	−53
186	−52
465	−55
186	−48
465	−48

followed as in the previous experiments, with the exception that the normal load rather than the surface velocity was the variable. For a particular normal load, the temperature of the ethyl alcohol bath was gradually increased from —80° C., and the frictional force measured continuously to determine the transition temperature. Table II gives these transition temperatures for successive runs with the loads indicated. It is apparent from this table that the normal load has no significant effect on the transition temperature.

The Effect of Various Fluids on the Transition Temperature of the Copper-Copper Couple

Of perhaps more significance than either sliding velocity or normal load is the effect of the kind of liquid environment in which the couple is immersed. One might then be able to draw significant conclusions about the degree of boundary lubrication provided by the fluid. This particular problem is a large and complex topic, and the investigations carried out in the present paper are merely to investigate the uniqueness of the transition temperature exhibited by the couple in the fluid rather than the role played by a particular fluid in providing boundary lubrication. The fluids used in each case were chemically pure. The water was deionized. The transition temperatures obtained were found for the same normal load and sliding velocity. New couples were employed in each case. Table III shows the results of this particular investigation. It will be noted that a wide range in transition temperatures occurs for the various fluids tested. In the case of trichlorethylene, no transition temperature was observed up to the boiling point of the liquid, and the friction coefficient was extremely low throughout the entire range of temperatures explored. When a small quantity of trichlorethylene was added to ethyl alcohol, the transition temperature of that solution rose to values above 50° C. For water, the transition temperature apparently was below the freezing point. Mercury, up to 200° C., did not produce a transition in sliding. It is felt, however, that the role of mercury is different than that for other fluids tested. Because of the solubility of copper in mercury, points of high pressure and temperature on the contact surface presumably are more soluble in mercury, and the resulting alloy may reduce the bonding strength of mating asperities.

Nickel-Nickel in Ethyl Alcohol-Water Solutions

The nickel vs. nickel disk and rider combination was also explored to obtain additional information on the nature of the phenomenon under study. As will be discussed later, the results reported here strongly suggest that a diffusion mechanism offers a plausible explanation for the effects observed. If this is the case, a shift in transition temperature would occur with each metal couple explored and, as a rough guide, this change would be expected to be in

Table III

Transition Temperature of Copper-Copper in Various Fluids
Normal Load — 373 grams
Sliding Velocity — 21 in./min.

Fluid	Approx. Transition Temp., °C
Ethyl alcohol	−65
Butyl alcohol	−40
Acetone	−15
Hexane	−8
Paraffin oil	+34
Trichlorethylene	>50
Water	<0
Mercury	>200

the same direction as the change in melting point of the couple.

This particular couple was first tested in water, and it was found that the transition temperature occurred between 0 and 10° C. The proximity of this temperature to the freezing point made it quite difficult to alternately damage and repair the sliding surface. On the other hand, in ethyl alcohol the transition temperature of the couple appeared to be greater than the boiling point of the fluid. The increase in the ethyl alcohol transition temperature, when shifting from the copper to the nickel couple, is in line with the melting point criterion of the preceding paragraph.

In order to obtain a fluid which has a transition temperature for the nickel-nickel couple in a convenient working range, various alcohol-water mixtures were examined. It was found that transition temperature was directly related to the alcohol concentration. A 50% alcohol-water solution (by volume) had a critical temperature of about 30° C. (depending on the sliding velocity) and provided sufficient flexibility for study.

Figure 6 shows the results of sliding below and above the transition temperature. The coefficient of friction in a 50-50 alcohol-water solution in which the temperature was kept below 6° C., did not exceed 0.92. The mechanism for sliding appears to be by shear, as defined above.

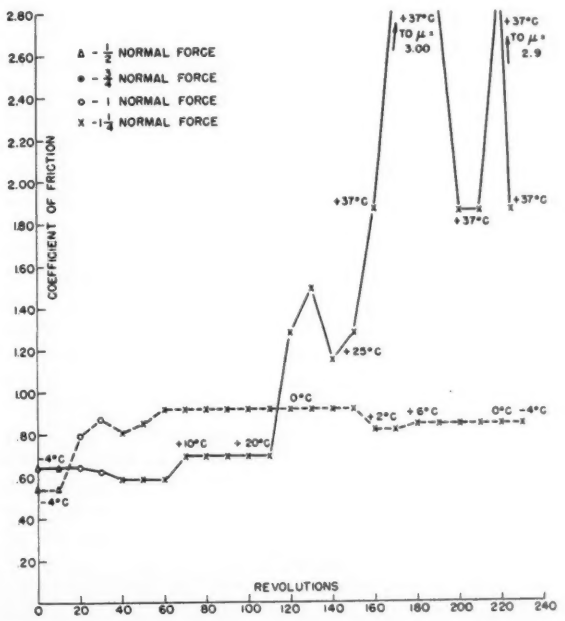


Figure 6. Nickel Rider vs. Nickel Disc in mixture of 50% ethyl alcohol and 50% water.

On the other hand, in the case of sliding for 110 revolutions at temperatures not exceeding 20° C. followed by 110 revolutions at temperatures up to 37° C., welding between the mating surfaces is definitely indicated. For the first 110 revolutions, the friction coefficient did not exceed 0.70; while for temperatures above the transition, friction coefficients as high as 3.0 were measured. The results then are quite similar to the copper-copper couple.

DISCUSSION OF RESULTS

The striking difference in sliding characteristics of mutually soluble couples immersed in a liquid and subjected to varying temperatures requires a satisfactory explanation which should also be helpful in adding to our general understanding of the sliding process. The most obvious interpretation of the phenomenon is that local boiling is taking place at the interface which can reduce boundary lubrication or permit high contact temperatures. As shown above, however, variation of the sliding velocity, other conditions being equal, produces a change in transition temperature which is in contradiction to this explanation.

An interpretation of the effect in which the development of strong local welds occurs through a process of diffusion offers a plausible qualitative explanation of the effect. To pursue this point of view, one needs to get a clearer picture of the nature of the interaction between mating asperities. In a recent paper[8] this interaction was described in terms of conformity or continuity of the structure of the mating materials across the interface. When couples, which exhibit solid solubility or which form intermetallic compounds according to their phase diagrams, slide in contact strong interfacial bonds are found. These bonds are attributed to the mobility of the surface atoms induced by very high local pressure and temperature (for a gaseous atmosphere), together with the mutual solubility or compound formation of the mating asperities, which permits a continuity of structure across the interface. Thus, when fracture of the junction region takes place, it occurs with an appreciable force and the break may occur in the base structure rather than at the interface. This results visually in excessive surface damage and high friction as seen in Figures 1(a) and (b). On the other hand, for those couples which do not alloy in the solid state, conformity or continuity across the surface is not readily established, and a weak interface results. Fracture of this junction then requires less force, and damage is confined locally to the interface. This so-called "shear sliding" is observed in Figures 1(e) and (f).

Machlen and Yankee[7] have used the work of adhesion as a measure of solid phase welding. The concept of continuity or conformity across the interface is in line with this viewpoint and is merely a qualitative measure of the adhesion process. The interpretation which is given to the present tests, namely, that diffusion or mobility of atoms is required to permit the development of the continuity or conformity, is an added factor in the mechanism.

In the present series of tests involving couples which are mutually soluble, the development of interfacial conformity and strong adhesion is interpreted as a temperature-dependent process. When asperities come into contact with each other, deformation, fracture, or both must occur. The local pressure developed at the contact point is very high, with the result that a high degree of surface mobility can occur at the interface. This mobility is also dependent on time and temperature. Thus the degree of conformity which exists at the interface will depend on the time at which the interface is in contact and the temperature at the interface. When the time of contact is very short or the temperature of the interface low, surface mobility is reduced and the development of conforming surfaces inhibited. The result is that the interfacial shear strength is greatly decreased, and the externally applied forces can easily cause separation of the interface. When time and temperature are such as to produce surface mobility, the interfacial shear strength increases, the external forces must correspondingly rise, and separation occurs with considerable force and damage.

A factor which is present in tests performed in liquids, but which is not as significant in gaseous atmospheres, is the molecular adsorption of the liquid on the surface of the mating metals. Unquestionably, these adsorbed films act to reduce the adhesion at the points of contact and are, hence, important in determining the particular temperature at which sliding is transformed from that of shear to that of welding. The significant difference in transition temperature for various liquids, as given in Table III, is indicative of the importance of adsorption on the mechanism of sliding.

Rabinowicz and Tabor[9] have studied the sliding behavior of metals in various liquids using radioactive methods for determining metal transfer and pickup. They reported a transition temperature for copper sliding against a fresh surface of copper in such liquids as cetane, light paraffin oil, cetyl and octadecyl alcohol, palmitic acid, and cupric palmitate. The results of the present paper are in close agreement with the observations of Rabinowicz and Tabor. They find that below the transition temperature, the friction is low as is the metal pick-up; while above the transition temperature, stickslip occurs, friction is high, and severe pick-up takes place. They interpreted the effect as being due to a change in state of the surface film with temperature such that desorption of the film occurred with increasing temperature.

The present experiments on velocity of sliding (Table I) seems to refute, at least in part, the explanation of the phenomenon from the point of view of the desorption of the surface film. The lowering of the transition temperature with decreased sliding velocity indicates that the behavior is not entirely temperature-dependent. The fastest rotational speed of the disk was 3 rpm, such that ample time is available for reforming an adsorbed film on the surface of the disk following each revolution. Thus, the velocity effect must be related to the behavior of the metals themselves.

Another result in the present investigation indicates that adsorption and desorption of the surface monolayers do not fully explain the transition in sliding characteristics. In comparing the sliding behavior of nickel vs. nickel in liquids, it is observed that a distinct shift in transition temperature occurs for both liquids. In the case of ethyl alcohol, the transition in sliding appears to be at the boiling point of the fluid; while for copper vs. copper, the transition is at —65° C. Thus, a shift of 143° C. occurs between the two metals, a change of which is difficult to explain in terms of adsorption or desorption with temperature, particularly since the alcohol does not react with either metal surface. Again it would appear that the mobility of the metal surfaces as well as the boundary lubricating qualities of the liquid are related to the transition effect.

Some recent experiments of Bowden are of interest in connection with the discussion of sliding velocity.[10] Here a steel sphere rotating at high speed is brought in contact with a copper plate. From the measured friction coefficients and photographs of the contact area on the copper plate, it was observed that as the speed was increased, the friction coefficient dropped and the character of the contact area changed from one which was a rough and highly abraded to a smooth, highly polished area. For example, at low speed a friction coefficient (μ) of 5 was measured, while at 500 mph, $\mu = 0.9$; at 1000 mph, $\mu = 0.2$, and at 1500 mph, $\mu = 0.2$. Contact areas of high and low speed are quite similar in appearance to those of Figure 3 below and above the transition temperature. The similarity in behavior of the friction coefficient and appearance of contact area suggests the presence of a transition effect in these dry, high-speed, sliding tests. Bowden describes the effect as being due to melting of the copper. An alternative mechanism suggested in the present paper also appears plausible, namely, that weak adhesion exists because of insufficient time or temperature to develop interfacial conformity.

Figure 3 indicates that when operating above the transition temperature under repetitive sliding conditions, a delay time occurs before interfacial adhesion becomes sufficiently strong to develop local welding, high friction, and surface damage. This delay time is somewhat puzzling and needs explanation. The interpretation given here is that several repetitions of sliding over the same surface is required to remove adsorbed films other than that provided by the liquid environment. Fresh disks and riders were used for each run, and the surfaces were carefully cleaned. However, all surface-protecting films were certainly not removed until wiped off by the repeated mechanical action of the sliding process. The increase in delay time with decreasing temperature is attributed to the combined effect of gradual removal of the adsorbed surface layers and the decrease of surface mobility of the metallic interfaces. The removal of the adsorbed contaminating layer is assumed to occur independently of the temperature, while the development of strong interfacial welds through diffusion decreases sharply with decreasing temperature. In the case of the run at —65° C. in Figure 3, the temperature is such that the interfacial strength is marginal, and the sliding conditions alter between shearing and welding.

The rise in transition temperature with repetitions of damage and repair is indicated in Figure 5. Here the transition temperature is measured as that temperature where a sharp rise in friction takes place. This change in transition temperature with repetitions of damage and repair may depend on the particular state of the surface prior to increasing the temperature above the transition value. Thus, prolonged sliding and deformation by shear at subtransition temperatures might lead to a gradual mechanical mating of the disk and rider surfaces. When the surfaces are well lapped, the temperature necessary to cause the transition in sliding characteristics might be higher than otherwise. This is because the polished, cold-worked surfaces fit closely together so that the subsequent local temperatures and pressures generated there are lower and less likely to weld together. Thus the prior surface condition, as defined by the number of revolutions of sliding below the transition temperature, can be quite important in the study of the phenomenon.

CONCLUSIONS

Based on the results found in this investigation, the following conclusions can be drawn:

(1) Two distinct sliding processes exist for metal rubbing pairs or couples having mutual solubility, depending on the liquid environment, temperature, and sliding velocity.

(2) Sliding by shear is found for couples below a critical temperature defined as the "transition temperature." Shear sliding is characterized by low friction, and lack of interfacial welding and surface damage.

(3) Sliding by welding occurs for mutually-soluble metal couples in liquids above the transition temperature, and is characterized by high friction, local welding, and severe surface damage.

(4) The transition in sliding characteristics appears to be reversible, i.e., raising the temperature through the transition temperature increases the friction and surface damage; subsequent lowering of the temperature causes the sliding to return to the shear type as indicated by a lowering of the friction coefficient and reduction in further surface damage.

(5) The transition temperature is found to depend on the boundary lubricating qualities of the liquid, the choice of couple, the sliding velocity, and previous history of sliding.

(6) The transition temperature appears to be independent of applied load.

(7) From the observations reported in this paper, surface diffusion at the interfaces of mating asperities is considered to be important in the development of weak or strong junctions.

BIBLIOGRAPHY

1. Bowden, F. P., A. J. W. Moore & D. Tabor, *J. Appl. Phys., Vol. 14,* 1943, p. 80.
2. Bowden, F. P., *Proc. Roy. Soc., New South Wales, Vol. 78,* 1945, p. 187.
3. Bowden, F. P., & T. P. Hughes, *Proc. Roy. Soc., Vol. 172A,* 1939, p. 263.
4. Bowden, F. P., & J. E. Young, *Nature, Vol. 164,* 1949, p. 1089.
5. Ernst, H. E., & M. E. Merchant, "Surface Friction of Clean Metals, A Basic Factor in the Metal Cutting Process," Proceedings of the Special Summer Conference on Friction & Surface Finish, Massachusetts Institute of Technology, Cambridge, Mass., June 1940.
6. Roach, A. E., C. L. Goodzeit & P. A. Totta, "Score Resistance of Bearing Metals," *Nature, Vol. 172,* 1953, p. 301.
7. Machlin, E. S., & W. R. Yankee, "Friction of Celan Metals & Oxides with Special Reference to Titanium," *J. Appl. Phy., Vol. 25,* 1954, p. 576.
8. Coffin, L. F., Jr., "A Study of Sliding of Metals with Particular Reference to Atmosphere," *Lubrication Engineering, Vol. 12,* 1956, p. 50.
9. Rabinowicz, E., & D. Tabor, "Metallic Transfer Between Sliding Metals," *Proc. Roy. Soc., Vol. 208A,* 1951, p. 455.
10. Bowden, F. P., "Recent Studies of Metallic Friction," *The Engineer, Vol. 198,* 1954, p. 902.

ACKNOWLEDGEMENT. The author would like to acknowledge the assistance of Donald T. Groleau for his skill and care in performing the experimental work reported in this paper. He is further indebted to the Knolls Atomic Power Laboratory (operated for the U. S. Atomic Energy Commission by the General Electric Co.) for support of this investigation.

—SYMPOSIUM ON INDUSTRIAL DERMATOSES —

(Final Article of a Series)

"I believe that one of the big mistakes that has been made in industry is that many employers have not provided their workers with good medical care," asserted Dr. Leonard Weber, clinical professor of dermatology at the University of Illinois, speaking at an American Society of Lubrication Engineers symposium on industrial skin diseases.

When a workman develops dermatitis while working in a plant, the plant must care for him until the eruption has cleared. Today less than 30 per cent of United States workers are given in-plant medical service.

To help fight the problem of industrial dermatitis, here are some of the points made by doctors and engineers at ASLE's tenth annual meeting:

1. *Pre-employment examinations should be given to prevent the spread of industrial skin diseases. Dr. Clarence Livingood of Detroit's Henry Ford Hospital, the session chairman, cautioned against employing a person with a skin condition of any kind. He warned that if anything happened to aggravate that condition, it would be blamed on factors associated with the person's work.*
2. *Industry should be more cooperative in providing doctors with the formulae and ingredients used in new additives. The panel recognized the sharp competition in the additive industry by suggesting that manufacturers who are hesitant to reveal their formulae should conduct their own toxicological research to determine whether any potentially harmful elements are contained in the additive.*

   If a firm wants information concerning an additive it plans to use, this information may be obtained from the United States Public Health Service.
3. *Protective creams shouldn't be used as treatment for skin outbreaks. These creams are protective; they're not cure-alls.*

The panel of six doctors and two lawyers at the April 1955 ASLE Symposium on Industrial Dermatoses evaluated the possibility of specific cutting and lubricating oils causing industrial dermatoses. For your further information, below are proceedings of the final meeting of the ASLE tenth annual symposium.

The Industrial Dermatosis Panel: Questions & Answers

Editors Note: This is the last of the series of articles based on the Symposium on Industrial Dermatoses. The ASLE panel chairman was Dr. Clarence Livingood, Physician-in-Charge, Division of Dermatology, Henry Ford Hospital, Detroit, and the panel members were:

Dr. Donald J. Birmingham, Medical Director, Chief Dermatologist, U. S. Department of Health, Education and Welfare, Cincinnati, Ohio
Mr. M. L. Beardslee, Resident Engineer, Wayne Plant, Detroit Diesel Engine Division, General Motors Corporation
Dr. E. A. Irwin, Medical Director of the Ford Motor Company
Mr. Nobel H. Schell, Lubrication Engineer, Fort Wayne Works, International Harvester Company
Dr. John M. Shaw, Instructor in Dermatology, University of Michigan School of Medicine
Dr. Leonard Weber, Clinical Professor of Dermatology, University of Illinois
Dr. W. C. Witham, Program Co-ordinator, Department of Chemistry and Chemical Engineering, The Armour Research Foundation

SESSION CHAIRMAN: I have asked Dr. Irvin to open this part of the Symposium with a brief discussion of the problem as viewed by the industrial physician.

DR. IRVIN: There are many skin conditions which present definite problems to the industrial physician and oil exposure is blamed for many of these conditions. Dr. Birmingham has emphasized a point which is frequently overlooked — he said less than 30 percent of the workers of this country are given in-plant medical service. This fact makes it rather difficult to develop valuable statistics and to evaluate the real problem. Industrial dermatoses are not serious from the standpoint of severity, but rather from the standpoint of frequency. In my experience, this condition is the most common of all occupational diseases.

The industrial physician has some very practical problems which the Panel may help to answer.

1. Too many physicians and even dermatologists blame the employees' work for every type of dermatitis.
2. Better cooperation is required with physicians

and dermatologists in regard to requests for job changes.

3. Dermatologists should become more familiar with the work environment of a patient before calling the condition occupational and even before requesting a transfer to another type of work.

4. Assistance is needed from the authorities as to how we may recognize the individuals who will have difficulty with their skin. Patch testing is too time consuming and is not practical, from our point of view. We need assistance from the Panel in regard to job placement.

Allergy is a condition which gives all physicians trouble, but it really gives the industrial physician great problems. Too many skin conditions are called occupational when they are really on an allergic basis. Allergy should be the individual's responsibility and the employer should not be held liable for these conditions.

There should be greater understanding on the part of employers, labor leaders, practicing physicians, and even the patients themselves, in regard to the problems encountered when transfers are requested from one type of work to another. It is not always easy to obtain transfers with the complications of union seniority, job classifications, lack of job training, etc.

I hope this Panel will have time to answer some of the questions which I have raised.

SESSION CHAIRMAN: Thank you, Dr. Irvin. I am sure that essentially the other members of the Panel, especially the dermatologists, will agree with your remarks. I hope that the discussion to follow will result in satisfactory answers to at least some of your questions. Here is the first question.

Is there appreciable evidence that skin cancer (or other types of cancer) is caused by working in the presence of or contact with petroleum oils of the non-additive type?

The second part of this question refers to the same subject, that is, is there any evidence that skin cancer is caused by additive type petroleum oils, particularly sulphur, chlorine, or phosphorous compounded?

Dr. Birmingham, will you open the discussion on this important subject?

DR. BIRMINGHAM: There have been reports in the literature that skin cancer has occurred from contact with cutting oils. The suspicions which surround this problem, however, over-shadow the actual evidence. Some outstanding investigators have shown that certain oils do have carcinogenic fractions attached to them. The evidence which Dr. Weber presented casts more suspicion on this topic. In my experience, so far as regular cutting oils are concerned, there has been no evidence to show that these materials are carcinogenic. We have been observing operations dealing with shale oil and its products among a group of 200 employees for four years, and as yet we have not noticed any carcinogenic effect of American shale oil. It must be borne in mind, however, that the time element (four years) is insufficient from which to draw conclusions.

SESSION CHAIRMAN: For practical purposes, then, except for occasional cases, the answer to the question is no?

DR. BIRMINGHAM: Yes.

DR. WEBER: This subject interested me some years ago, especially during the war years, and I thought that we would probably see an increase of skin cancer, particularly on the forearms and hands of some of the workers in this industry who had trouble from the oils. I have had occasion to reexamine some of these men during the last few years, and I have been unable to find evidence that cancer has developed. I have been asked this same question by various companies, and my answer has always been no.

I might clarify one point in reference to one of my slides which illustrated a worker with skin cancer following an oil explosion. I did not mean to infer that the cancer was due to the oil: it is my opinion that it was secondary to the burn rather than the oil.

SESSION CHAIRMAN: Occasionally, I have seen patients who have developed cancer on the skin of the face or the dorsum of the hands following a burn due to a spicule of hot metal. I have been inclined to accept these cases as occupational. What is your experience in this regard, Dr. Weber?

DR. WEBER: Briefly, I would like to relate my experience in that connection, particularly with one company near Chicago, which had a number of these cases a few years ago: they were in an older group in which we could expect cutaneous cancer, and for three or four years they provided medical care for these patients. Incidentally, they changed their insurance carrier, and the new insurance company decided they would not accept these cases as occupational. Since then we have had no more complaints. At the present time, I am undecided about these cases.

SESSION CHAIRMAN: We have a number of questions here which I have scanned hurriedly; they refer to the role of bacterial infection in the etiology of dermatitis due to cutting and lubricating oils. For example, three of these questions are as follows:

Are most industrial or oil dermatoses bacterial in nature? If so, which type of germicide or bactericide has been most effective in arresting the bacterial growth?

Do you think that the bacterial flora of soluble oil emulsions in industrial plants, which are known to contain pathogenic microorganisms, may be a contributory factor in industrial skin diseases?

With respect to soluble oils, do you consider bacterial organisms to be primary or secondary invaders in dermatitis; if secondary, do you attribute the flora of the skin or the flora of the water mixed with the oil as the chief offender? Also, does antagonism exist between these organisms?

I think we can cover this subject and answer all of these questions at one time. I will ask Dr. Shaw to open the discussion on this subject.

DR. SHAW: I am interested in this subject. As a matter of fact, getting into the protective ointment problem brought me in contact with the soluble and insoluble cutting oils of the various small plants around Ann Arbor.

On three different occasions, samples were collected of the soluble and insoluble cutting oils, and cultures were grown in serial dilutions to see what bacteria were present. It was observed that the insoluble cutting oils, whether they were brand new — just out of the drum — or whether they had been in operation for as long as six months, did not support large growth of bacteria. In other words, insoluble cutting oils are relatively free from bacteria. The soluble cutting oil emulsions, on the other hand, were found to contain increasing numbers of bacteria in direct proportion to the length of time the oil had been in operation. In a

new emulsion, the bacterial content was very low with occasional colonies of gram positive cocci recovered.

There was one emulsion which had been in use for nine months in one plant. It was dirty, full of shavings, and loaded with bacteria. Even the one to ten thousand dilution had many colonies on the plate. These organisms cultured out as gram negative rods of the coliform group.

The workers in this oil had no difficulties of the skin, and it is my opinion that dermatoses of workers exposed to cutting oils are caused by secondary invaders, and not primarily from organisms in the cutting oils.

SESSION CHAIRMAN: Thank you, Dr. Shaw. Will you continue the discussion, Dr. Birmingham?

DR. BIRMINGHAM: I am in complete agreement with Dr. Shaw's statements. In certain outbreaks of dermatitis which the Public Health Service has investigated, the cause was established as being due to phenolics or mercurials which had been placed in the cutting oils in order to prevent dermatoses. Consequently, many of those men who ordinarily would have tolerated the bacterial climate, developed occupational dermatitis due to the mercurials or phenolics.

SESSION CHAIRMAN: Then you do not advocate adding disinfectants to the cutting oils?

DR. BIRMINGHAM: One cannot state that these compounds should not be added to the oils, but they have definitely caused dermatitis in certain instances. They have a practical value of inhibiting rancidity of the oil.

SESSION CHAIRMAN: We have a specific question in regard to the addition of hexachlorophene to cutting oils as a preventive of bacterial contamination.

DR. BIRMINGHAM: I am not certain of the antibacterial efficiency of hexachlorophene when it is added to oil and undergoes continuous usage in a cutting machine. We know that it does have value as a degerming agent on the skin.

SESSION CHAIRMAN: What do you think of the use of hexachlorophene in soaps?

DR. BIRMINGHAM: One of the disturbing factors in the publicity attending these products is whether or not the skin actually needs to be rid of bacteria which ordinarily live in symbiosis. There is some rationale, however, for the use of these materials by the surgeon.

SESSION CHAIRMAN: Will you close the discussion of this important subject, Dr. Weber?

DR. WEBER: I have only one point that I would like to add. I have always thought that a significant number of the patients who have had trouble with oil folliculitis were persons who have an unusual susceptibility to bacterial infections, such as boils.

I feel reasonably certain that the bacteria that are present on the worker's skin have a great deal to do with the severity of the folliculitis or, let's say, oil boils, as they are so commonly called.

SESSION CHAIRMAN: Thank you. The next question is Have you had any cases of the worker breathing soluble and/or insoluble cutting oils?

Dr. Birmingham, I will ask you to answer this question.

DR. BIRMINGHAM: We have seen no cases; however, a few inquiries have come to the attention of the Public Health Service casting suspicion on this problem. Research in lubricating engineering should be directed toward investigating what phenomena may occur in jet spray operations where certain oils can get into the atmosphere and become available for breathing.

SESSION CHAIRMAN: Dr. Irvin, do you think that breathing of oil fumes is of any importance?

DR. IRVIN: I think it is, from a nuisance standpoint, but if the machine is properly functioning there should be no excuse for it. When a machine is not functioning properly, there may be a spray which is in the breathing zone and this should be controlled. There is no excuse for having oil mist in the breathing zone, and from a nuisance value I think it should be controlled. There is a possibility that it may have some deleterious effect, but to my knowledge no one has definitely proven this.

MR. BEARDSLEE: We had a rather interesting experience along that line. We started up a new operation where the tool was turning at a very high speed; we had sulphurized mineral oil in the machine; after about four hours on this machine the operator complained of abdominal cramps and diarrhea, and a second operator on the same machine in a like period also had diarrhea. We came to the conclusion that there was sufficient inhalation of this oil to cause a reaction similar to a large dose of castor oil. Neither operator had any serious after effect following the catharsis. But, needless to mention, we corrected the condition as quickly as possible.

SESSION CHAIRMAN: Thank you. We will go on to the next question.

We are often asked to advise consumers on whether any of the constituents of an oil are dangerous and/or irritant. How can this be answered, except to state what the actual constituents are?

There is a difficult one to answer. Who wants to volunteer? Dr. Birmingham.

DR. BIRMINGHAM: Few of us outside of the lubricating oil business can keep abreast of the additives. I do not know what many of them will do to the skin in particular or the body in general; however, when additives of known harmfulness, for example, certain chlorinated hydrocarbons, are placed in oils, one can definitely expect trouble to occur as a result of contact with them. This problem was well demonstrated in the cases of chloracne which Dr. Weber presented. Chloracne can and does occur from cutting oils, and most of us who frequently visit plants have seen its presence among certain workmen. In order to develop chloracne, however, one must be exposed to chlorinated naphthalenes or chlorinated diphenyls. To the best of our knowledge, chlorine of itself is not sufficient to cause chloracne. In addition to the skin manifestations, contact with these chlorinated hydrocarbons can cause liver damage and nerve injury. With respect to other additives, it is difficult to develop a product which is universally innocuous; however, if companies producing cutting oils will spend more time in the study of the toxic effects of the oils and additives, they will be farther ahead in producing better compounds.

SESSION CHAIRMAN: Here is another question for Dr. Birmingham:

If a given company wanted to get information on an additive that they plan to use, is there any information service available, or would it be feasible for them to write to any Government Bureau, such as the U. S. Public Health Service?

DR. BIRMINGHAM: Sometimes the Occupational Health Field Headquarters will have available information on these additives; however, there are other organizations such as the Kettering Laboratory in Cincinnati, and the American Petroleum Institute where information may be available. Further, some of the manufacturers of the additives may have well-controlled toxicity data. The Mellon Foundation devotes considerable time to the study of industrial toxicology and may likewise be of assistance. Sometimes source material is not available in our laboratory. As a rule, however, the Public Health Service will provide any information which they have on a particular subject.

SESSION CHAIRMAN: Do you have any comments on this, Dr. Weber?

DR. WEBER: I would like to state that if we had more cooperation with industry in providing us with the formulae and the ingredients of the various things they use, it might be helpful in a good many instances. I am not convinced that these products should be secret. We have an expert chemist here, and maybe he has an idea about some of the secrets of these various compounds.

DR. WITHAM: As is well known, the selling of cutting oils is on a highly competitive basis and every effort is made to keep the composition of the products confidential. If you have spent a considerable number of research dollars in developing a cutting oil which places you in a favorable competitive position — I should have said in developing an additive for a cutting oil — you do not want to broadcast it.

Now, regarding the position of the additive manufacturers, I think it is almost common practice when they are coming out with a new additive, be it for cutting oil, lubricating oil, or any type of petroleum product which is going to be contacted manually with the public, that they conduct their own toxological research, because they are in an extremely vulnerable position if they release a product which they did not know would have an adverse effect.

SESSION CHAIRMAN: The next question is addressed to Dr. Birmingham, and he has answered it already, I suppose:

Do you consider the U. S. Department of Health records as a true current overall (U. S.) estimate of the situation? If so, don't you feel that publicity in reference to the responsibility of petroleum products is unduly stressed?

DR. BIRMINGHAM: As these records stand they are correct; however, the data have been collected from a small group of focal points. Out of 48 states, only 11 were able to furnish us with statistics on occupational diseases because they are not always recognized, and even when they are diagnosed, there may be a failure to report the disease. One must be aware also that some cases are reported as occupational which are probably not occupational in origin. We consider these statistics to be relatively reliable. As far as publicity in the problem is concerned, the Public Health Service has been interested in the investigation and prevention of occupational skin disease since 1928 when Dr. Louis Schwartz began his work in this field.

SESSION CHAIRMAN: Thank you. The next question is rather long:

Would it be appropriate to state that occupational dermatitis is related to the conditions which result in the disease — namely:

1. **Defatting of the skin.**
2. **Closure of pores with inclusion of bacteria.**
3. **Absorption of chlorine compounds, etc.**

And that any lack of suitable protective efforts is the real cause — not the oil or solvent itself?

Would you like to comment on that question, Dr. Weber?

DR. WEBER: I think that, for the most part, defatting of the skin occurs more in connection with some types of oils.

The closure of pores is more apt to occur with exposure to the insoluble type of oil.

The effect of chlorine compounds was demonstrated in the photographs that I showed.

As to the lack of suitable protective efforts, that is something that we are looking for.

SESSION CHAIRMAN: In this connection, Dr. Shaw, I would like to ask you a question that I am sure you can answer:

Do you, or do you not, recommend the routine use of one of the protective ointments in an effort to prevent oil dermatitis? How about the occasional use for a specific worker?

DR. SHAW: I cannot recommend the routine use of protective ointments. The cost would be prohibitive.

For the occasional use on selected individuals, I think it can be of definite value. The choice should depend upon both the individual and the noxious substance which the individual must contact.

As I pointed out, none of the protective ointments available today can be expected to repel solvents — kerosene, Stoddard's Solvent, and the like. None of them can be expected to repel for any length of time the heavy insoluble cutting oils. Therefore, routine use in these instances would not be of value.

SESSION CHAIRMAN: I might add also that these protective ointments are actually contraindicated in the worker who has dermatitis; at least, they are contraindicated until the dermatitis has disappeared completely.

We have observed a number of people who have actually had flare-ups of their dermatitis following the application of protective creams before the skin condition had cleared up.

Do you agree with that, Dr. Shaw?

DR. SHAW: Yes. That point cannot be too strongly stressed. The ointments are of preventive value only. They must not be used as treatment; they are not therapeutic ointments, they are protective ointments.

SESSION CHAIRMAN: The next question.

Are patch tests of synthetic soluble oils suitable for disapproving coolants for use?

How many persons should be tested?

Should the concentrate be tested, or a normal dilution used?

This is a question of great importance. Dr. Birmingham, I think that you qualify as one of the experts in this field.

DR. BIRMINGHAM: First of all, a patch test should not be done with any material that is a primary irritant. An irritant is simply a material that, when applied to the skin in sufficient concentration for a sufficient length of time, will cause a reaction in the majority of people. The

use of the patch test to determine whether or not an oil is a primary irritant is plausible, but this should be done on animals. The best time to study an oil for its irritant qualities is during the developmental stage. If patch testing is done with a material of high pH. one may produce a positive reaction. Therefore, proper dilution is highly important in performing patch tests. When people are suffering from dermatitis suspected as being due to an oil, patch testing can be done to determine whether or not the individual is allergic to the oil. It should be emphasized that patch tests are best performed by the plant physician or the consulting dermatologist, who understand the complexities of this procedure.

Dr. Weber emphasized the concern attending the use of patch tests. Too much reliance should not be placed upon it, for it is only a diagnostic aid. In attempting to determine whether a substance is an irritant, the test can be used on animals.

SESSION CHAIRMAN: Would you say that it is a fair statement that the trend is to use patch tests less frequently?

DR. BIRMINGHAM: I thing it is, yes.

SESSION CHAIRMAN: Does anyone else have any comments on this question? If not, the next question.

Is the general medical practitioner, having no knowledge of the complex nature of cutting and soluble oils, qualified to diagnose "shop" dermatitis?

What is your opinion, Dr. Weber?

DR. WEBER: I think if a general practitioner uses some common sense and keeps watching the same plant and the same employees over a period of time, he ought to be able to form an opinion.

I believe that one of the greatest mistakes that has been made in industry is that many employers have not provided themselves with good medical care. In some quarters there has been a tendency to provide medical care after something has happened; in other words, after the horse is stolen, they lock the barn.

A lot of money is spent on research but not enough on medical care.

SESSION CHAIRMAN: Dr. Irvin, you must have had an enormous practical experience along these lines. Will you please comment on this question?

DR. IRVIN: I think it depends on the individual. I don't think one can make a broad statement in regard to general practitioners because, as Dr. Weber says, it depends on the man, and some general practitioners do an excellent job.

The alert practitioner is a good man, and I think we have to accept his diagnoses and hold it in high regard..

SESSION CHAIRMAN: Are there any other comments on this question?

DR. IRVIN: Well, our biggest problem is to get any help in regard to compensation cases and that includes dermatologists. In some areas, every dermatitis case that comes into the office is occupational if the man is working, and that gives Industry a pretty big headache. We have had a lot of discussion today, but I have not heard anyone say when a case is compensable, or how to determine liability, or how to rule it out. That is a real big problem to us.

SESSION CHAIRMAN: I think it is appropriate to state that often the etiologic diagnosis of a dermatitis is a problem of considerable magnitude for even the most experienced dermatologist. In some cases, it is not possible to make a definitive diagnosis; also, frequently there is the question of aggravation of a pre-existing dermatitis by occupational factors.

The next part to that question is:

Was the condition called "chloracne" definitely proven as such by patch tests or other artificial means employing chlorinated products?

DR. WEBER: I think that has been definitely proved by, let us say, usage tests; in other words, those that have worked with chlorine products developed chloracne, and when such exposure is discontinued they improve; and when you return them to the job and the same disease develops again, you don't need any patch test to prove the relationship.

SESSION CHAIRMAN: Is there any other comment on this?

The next question.

Would you comment on the relative skin toxemia between petroleum lubes of the:

1. **Glycol-water base types;**
2. **Organic phosphates;**
3. **Diester lubricants?**

Will you open the discussion on this, Dr. Witham?

DR. WITHAM: The glycol-water base types would have the same effect on skin as the ordinary type.

Organic phosphates, such as trichlorethyl, I do think have a very definite skin irritation. If you have a lesion on your hand you are going to get a reaction.

The diester lubricants, to my knowledge, are not active on the skin, but the organic phosphates can be.

SESSION CHAIRMAN: The next question reads as follows:

Please discuss the influence of occupational factors on psoriasis; does this condition respond to any kind of treatment?

As Dr. Weber pointed out, any factor which irritates the skin, whether it be trauma incident to an abrasion, or the effect of a chemical allergen or irritant, will tend to cause new lesions of psoriasis in persons who have the disease; thus, often cutting oils and lubricants of various types will aggravate the disease.

Does this condition respond to any kind of treatment? Yes, psoriasis is treatable, but it is not curable. However, in most instances, the disease can be controlled by appropriate treatment.

Dr. Irvin has asked us to discuss pre-employment examinations from the standpoint of prevention of occupational dermatitis. How far should industry go in this direction, and how effective is such a program in decreasing disability due to occupational dermatitis? Dr. Weber, will you open the discussion on this question?

DR. WEBER: I think that some of those points have been covered. I would like to say just a few words. I believe that a good deal could be prevented by pre-employment examination. I am well aware of the fact that it is difficult to obtain an accurate history from many of these patients. Upon checking with other sources, you find out they have falsified their answers to pertinent questions. I believe that pre-employment examination would eliminate certain groups that are likely to develop industrial dermatitis, however.

A physician who is well trained and knows about the skin can select certain types that are likely to have trouble. I feel that all of those persons who have an existing disease of the skin should not be employed in certain types of industry.

In other words, we know that there are more hazards in certain occupations than there are in others. I suppose that it will take a long time before pre-employment examinations will cover all of the new employees. Probably, one of these days the unions, as they keep on growing stronger, will become interested in this phase of the problem.

SESSION CHAIRMAN: Dr. Irvin, what do you do about this in your own plant, so far as the skin is concerned?

DR. IRVIN: I think it is very easy to detect the obvious cases. The borderline cases are very difficult to discover. If a man is examined with acne over his shoulders, face and neck, naturally you don't put him to work on a job with an oil exposure. It doesn't take great skill to detect such a case. It is the individual who shows no evidence of any skin condition, and no previous history, that gives us trouble. To the best of my knowledge, there isn't any way that you can discover these cases in advance.

We try to watch the complexions, because we find that certain types of individuals cause more trouble than others.

There is one question which is uppermost in the minds of a lot of men in industry, and that is whether or not you should routinely turn down people who have an irritation between the toes. Are those people more prone to get dermatitis on the arms and hands than those that do not have this irritation? From the standpoint of an employer that is a pretty practical question, and I would like to hear some comments on this.

SESSION CHAIRMAN: I would like to make a comment on this question.

In my opinion the importance of chronic fungus infections is overemphasized. I do not think that persons with a little scaling and maceration between the toes due to a low-grade fungus infection are any more apt to develop occupational dermatitis than a person who does not have such involvement.

Dr. Birmingham, do you disagree with this opinion?

DR. BIRMINGHAM: No, not at all. That has been our experience in the study of dermatoses in industry..

SESSION CHAIRMAN: Dr. Weber?

DR. WEBER: It is very difficult to convince these people that the eruption on the hand may be secondary to the eruption on the feet, and that is particularly true if they are in an occupation where there are known industrial sensitizers. I think that is a very important question. I have felt those patients that have ring-worm infection are more likely to develop sensitivities than those with normal skin.

SESSION CHAIRMAN: Dr. Irvin?

DR. IRVIN: That has been our experience, too, Dr. Weber; these people with lacerated feet are a poor risk. There is another risk that you assume, because invariably they will claim that the oil on the floor has aggravated it, and it presents a problem from the standpoint of labor relations, and from the standpoint of nuisance, too.

SESSION CHAIRMAN: I agree with your last point, Dr. Irvin. If you employ a person who has a skin condition of any kind, and if anything happens to it, and of course skin conditions including fungus infections do vary in their natural course, it will be blamed on factors associated with the person's work.

Now, finally, one last question that Dr. Irvin brought up, and that is this very important one of the liability of an employer for a continued recurrence of dermatitis, even if his job is changed, following one episode that occurred because of an occupational factor. In other words, for example, a person develops either allergic or primary irritant reaction in a given job by exposure to a given type of cutting oil; the condition clears up and he returns to work and it flares up, and everybody agrees that his job should be changed; he changes to another job, and because his skin has changed to the point where it is more susceptible to a primary irritant, and more susceptible to trauma, he has a flare-up in his condition; what is the responsibility of the employer? Will you discuss this important subject, Dr. Birmingham?

DR. BIRMINGHAM: When an individual develops dermatitis while working in a plant, the plant is responsible in caring for the workman until the eruption has cleared. Usually, the individual is returned to work, and quite frequently he can continue to work in that same exposure by using proper precautions. On occasion, a workman is given a job transfer, and despite continued absence from the original exposure, the eruption will continue to flare. Again, a workman may leave the original place of employment because of dermatitis, the eruption will heal, and with different employment and different exposures he will develop a new dermatitis. Frequently, the original employer is held responsible for the case. I doubt if one can answer this question to the satisfaction of all because of the many factors involved. For example, four dermatologists are participating in this panel discussion and all of them have opinions about this subject. The opinions may be widely diverse because of the circumstances surrounding the case in question. One can state that each case requires a thorough history concerning the onset, a complete examination of the nature and distribution of the eruption, and a good follow-up concerning the course of the disease. Patch tests may provide an answer. There is no hard and fast rule which can be followed in answering this question because each case presents an individual problem, and the doctor will form his own opinion regarding the specific case. Many intrinsic and extrinsic factors can complicate a case of occupational dermatitis.

SESSION CHAIRMAN: Dr. Weber, do you have any comments on this problem?

DR. WEBER: My opinion coincides with that of Dr. Birmingham.

SESSION CHAIRMAN: This concludes our question and answer period. On behalf of all of the members of the Panel, I wish to thank you for your kind interest and attention throughout.

MR. HOPKINSON: On behalf of the Society of Lubrication Engineers, Dr. Livingood, and Members of this Panel, we are very grateful and indebted to you for the time that you have spent here, and for supplying from your generous fund of knowledge answers to the problems that seem to confront our Society.

ASLE MEMBERSHIP CLASSIFICATIONS

Membership in the American Society of Lubrication Engineers is in several grades as defined below. Assignment to grade is made by the Admissions Committee or Board of Directors on the basis of information submitted or supplied by references.

Members: Members shall be persons not less than 24 years of age who: (1) are engaged in research and instruction at technical schools, universities, and various publicly and privately supported institutions in the field of lubrication; or (2) have occupied recognized positions as lubrication engineers for a period of three or more (not necessarily consecutive) years prior to date of admission, involving the responsibilty for or supervision of the development, selection, field use and application of lubricants as differentiated from other activities; or (3) are indirectly concerned with the field of lubrication, but possessing other qualifications of experience, knowledge, and accomplishment, and have manifested a particular interest in the purposes and welfare of the Society to the extent that their membership would be a valuable contribution to the successful functioning of its activities. Fee $15.00.

Associate Members: Associate Members shall be persons less than 24 years of age, and those who do not completely fulfill the membership requirements for Members. Fee $7.50.

Sectional Sustaining Members: are such persons or organizations as may be interested in and desire to contribute to the support of the purposes and activities of a local Section of the Society. Fee $25.00.

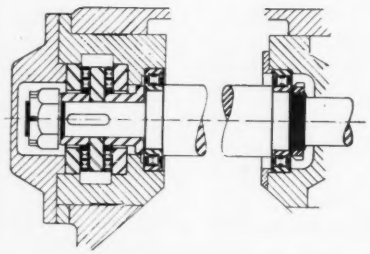
Industrial Members: Industrial Members are such persons or organizations as may be interested in and desire to contribute to supporting the purposes and activities of the Society. Fee $150.00.

For application blanks or further information, write:

ASLE
84 E. Randolph St.
Chicago 1, Ill.

New Products

BEARING WITHSTANDS THRUSTS



A double-acting thrust bearing (left, in bearing assembly for gear reduction unit above), designed to withstand heavy thrust loads from either direction, is now being manufactured. The flat-seat type bearing, with 2″ bore and 6 3/16″ o.d. consists of a center plate, two roller assemblies, two stationary plates, and two rotating inner sleeves. Thrust capacity is 17,550 lbs. at 750 rpm.

The right hand end of the inner sleeve is extended and heightened to contact the rotating inner race of radial bearings (center left). The ML radial roller bearing has radial capacity of 6,300 lbs. at 750 rpm.

For further information, write Rollway Bearing Co., 541 Seymour St., Syracuse, N. Y.

OILERS AID IN FEED CONTROL

Use of tapered feed adjustment screws provides simpler, more accurate feed control in these newly-improved multiple feed oilers. The operator can make quick finger-tip adjustments as the adjusting screws eliminate the need for conventional lock nuts.

Bulletin No. 33-A containing further information can be obtained by writing Trico Fuse Mfg. Co., 2948 N. 4th St. (LE), Milwaukee 12, Wisc.

NEW MOLD RELEASE SPRAY

New on the market is an aerosol-backed silicone spray mold lubricant said to be particularly suitable as a mold release agent for plastics and as an antistick coating in operations ranging from welding to pacing. For further information on Schuco Mold-Release Spray, write to Schuco Industries, 75 Cliff St., New York 38, N. Y.

LIFT RAISES DRUMS TO 72"

A hydraulic drum lift capable of raising drums and containers weighing up to 750 lbs. to a height of 72″ is now on the market. Actuated by a foot-operated pedal, this Model BM 3 "High Boy" heavy-duty steel drum lift is said to provide greater ease in pouring contents of containers and drums into mixing vats and tanks. Additional information can be obtained by writing Dept. LE, Sterling, Fleischman Co., P.O. Box 94, Broomall 3, Pa.

LUBRICANT ADHERES TO METAL

A molybdenum disulfide lubricant with an affinity for bonding to metal without building excessive accumulation on the surface, has been developed. In this lubricant, the maximum effectiveness of MoS_2 as an extreme pressure lubricant is said to be achieved by increasing the total surface area of the molybdenum disulfide through reduction of particle size. Additional information about Molykote, Type GX, may be obtained from the Alpha Molykote Corp., 65 Harvard Ave., Stamford, Conn.

NEW OIL LUBRICATION SYSTEM CAN ADJUST VOLUME CONTROL

An advanced "Meterflo" circulating oil system with a variable discharge pump and motor unit has been announced. Adjustable volume control is available in two ranges — from 5 to 30 and 16 to 100 cu. in./min. Positive discharge at any setting is said to be assured regardless of required system pressure.

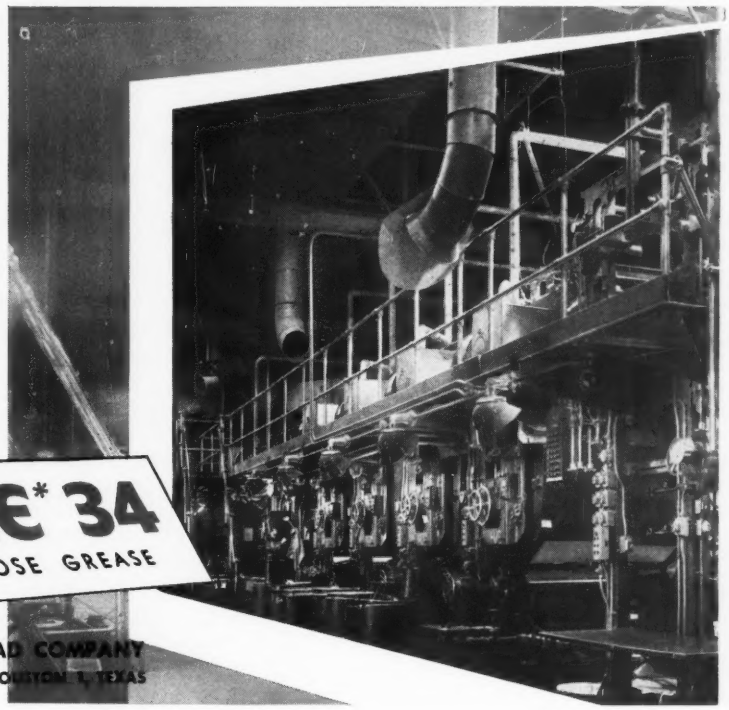
A hi-lo pressure switch which is part of the pumping unit is set for wide normal operating range and causes alarm signal lights to actuate if a bearing or line fails to receive oil due to high or low pressure or if there is a low oil supply or blocked oil line.

The hi-pressure dual cartridge filter can be replaced without stopping the system. For further information on the Mark II "Meterflo" system, write for Bulletin 574, Trabon Engineering Corp., 28787 LE Aurora Rd., Solon, Ohio.

BENTONE*34 based greases

resist leaching and cut costs

High-speed printing machinery poses a typical tough lubricating problem: what grease will stand up where the bearings are washed by solvents, thinners and leaching solutions? The Art Gravure Corporation of Cleveland, Ohio, standardized on grease made with Bentone* 34 and found that it stays in place, cuts maintenance cost, needs less frequent lubrication. Write for data and list of suppliers of grease made with non-soap, metal-adhesive Bentone 34.



Dutch Boy • TRADEMARKS REGISTERED

BENTONE* 34
FOR MULTI-PURPOSE GREASE

BAROID DIVISION • NATIONAL LEAD COMPANY
5732 P. O. BOX 1675 HOUSTON 1, TEXAS

BENTONE* 34 Grease Manufacturers and Distributors

THE ACME REFINING CO., Cleveland, Ohio
ADAM COOKS SONS, INC., Linden, N. J.
ALEMITE DIV., STEWART-WARNER CORP., Chicago, Ill.
ALLUBE CORP., Glendale, Calif.
THE AMERICAN LUBRICANTS CO., Dayton, Ohio
ARKANSAS FUEL OIL CORP., Shreveport, La.
BATTENFELD GREASE & OIL CORP., Kansas City, Mo.
BATTENFELD GREASE & OIL CORP. OF CALIFORNIA, Compton, Calif.
BATTENFELD GREASE & OIL CORP. OF NEW YORK, North Tonawanda, N. Y.
BEL-RAY CO., INC., Madison, N. J.
BOBBISH INDUSTRIAL PRODUCTS CO., Dearborn, Mich.
THE BROOKS OIL CO., Pittsburgh, Pa.
CASCADE PETROLEUM CO., Denver, Colo.
CATO OIL AND GREASE CO., Okla. City, Okla.
CONSUMERS COOPERATIVE ASSOCIATION, Kansas City, Mo.
CRAWFORD EMULSIONS, Pittsburgh, Pa.
DENS-OIL LUBRICANT CO., Kansas City, Mo.
JAMES W. DOYLE CORP., Detroit, Mich.
FISKE BROTHERS REFINING CO., Newark, N. J.
FISKE BROTHERS REFINING CO., Toledo, Ohio
THE FRANKLIN OIL AND GAS CO., Bedford, O.
GEORGIA-CAROLINA OIL CO., Macon, Georgia
GLOBE GREASE & MFG. CO., Los Angeles, Calif.
GOPLERUD LUBRICANTS CO., Mason City, Iowa
GREDAG, INC., Niagara Falls, N. Y.
HI-WAY REFINERIES, LTD., Regina, Sask., Canada
THE HODSON CORP., Chicago, Ill.
THE HODSON CORP. (QUEBEC), INC., Three Rivers, Quebec, Canada
E. F. HOUGHTON & CO., Philadelphia, Pa.
ILLICO INDEPENDENT OIL CO., Lincoln, Ill.
INTER-STATE OIL CO., Kansas City, Kansas
KEYSTONE LUBRICATING CO., Philadelphia, Pa.
LUBRICATION CO. OF AMERICA, Los Angeles, Calif.
MacMILLAN OIL CO. OF ALLENTOWN, Allentown, Pa.
MAGIE BROTHERS, INC., Chicago, Ill.
MAGNUS CHEMICAL CO., Garwood, N. J.
MANITOBA CO-OPERATIVE WHOLESALE LTD., Winnipeg, Man., Canada
METALCOTE OIL CO., St. Paul, Minn.
MID-STATES LUBRICANTS, Kansas City, Mo.
MIDWEST OIL CO., Minneapolis, Minn.
THE OHIO GREASE COMPANY, Loudonville, O.
OIL-KRAFT, INC., Cincinnati, O.
OIL DISTRIBUTORS OF PHILADELPHIA, Philadelphia, Pa.
ONYX INTERNATIONAL, Jersey City, N. J.
PANTHER OIL & GREASE MFG. CO., Fort Worth, Texas
PANTHER OIL & GREASE MFG. CO. OF CANADA, Toronto, Ontario, Canada
PENN-CREST OIL & GREASE CORP., Long Island City, N. Y.
PENN PRODUCTS CO., DuBois, Pa.
PHOENIX OIL COMPANY, Augusta, Ga.
A. B. PLATING SUPPLY CO., Milwaukee, Wisc.
PRAIRIE STATES OIL & GREASE CO., Danville, Ill.
PRECISION BEARING & TRANSMISSION CO., Omaha, Nebr.
RILEY BROS., INC., Burlington, Iowa
THE SAHARA OIL CO., DuQuoin, Ill.
SASKATCHEWAN FEDERATED COOP. LTD., Regina, Sask., Canada
ADOLF SCHMIDS ERBEN S. A., Bern, Switzerland
SERVICE LUBRICANTS, INC., Chicago, Ill.
L. SONNEBORN SONS, INC., New York, N. Y.
SOUTHWEST GREASE & OIL CO., INC., Wichita, Kan.
SOUTHWESTERN PETROLEUM CO., Fort Worth, Texas
SPECIALTY PRODUCTS CO., Jersey City, N. J.
SUNLAND REFINING CORP., Fresno, Calif.
SYRACUSE FIRE BRICK SUPPLY, Syracuse, N. Y.
THREE RIVERS REFINERY, Three Rivers, Tex.
TIDE WATER ASSOCIATED OIL CO., N. Y. C.
TIONA PETROLEUM CO., Philadelphia, Pa.
TOPSALL LUBRICANTS, INC., Kenmore, N. Y.
TOWER OIL CO., Chicago, Ill.
TRANSMISSION EQUIPMENT CO., Pittsburgh, Pa.
TRI-STATE PETROLEUM CO., Philadelphia, Pa.
UNITED COOPERATIVES, INC., Alliance, Ohio
UNITED PETROLEUM CORPORATION, Omaha, Nebraska
UNIVERSAL AVIATION SUPPLY, Wichita, Kan.
G. C. WAKEFIELD & CO., LTD., Toronto, Ontario, Canada
THE WARREN REFINING AND CHEMICAL CO., Cleveland, Ohio
THE WAVERLY OIL WORKS CO., Pittsburgh, Pa.
WESTLAND OIL CO., Minot, N. D.

*T.M. Reg.

BENTONE·34®

New Products

VALVES CONTROL HI-PRESSURES

Fluid control valves designed for pressures of 200 to 5,000 psi and ranging in sizes from 1/8" through 3/4" have been developed for air, oil, or water hydraulic use.

The Flow Control Valve's body design combines two types of valves—a floating retro-ball check which provides full flow in one direction, and a tapered, fine-thread needle which adjusts the flow in the opposite direction.

The valves can be utilized to control inlet and exhaust speed for double acting cylinders and cylinders in parallel. They can also be applied for two-way speed control of a hydraulic pumping system.

Catalog can be obtained by writing to Jack Modrich, Modrich Fluid Controls, Inc., 458 Virginia St., Crystal Lake, Ill.

FILTER WITH AUTOMATIC DRAIN

Simplified design of drain mechanism, more efficient liquid removal and a wider pressure and temperature operating range is claimed possible through use of automatic-drain air line filters. Simplification of the drain mechanism is said to result in fewer parts and increased efficiency in filtering operation. Filters for transparent bowls operate at air pressures from 5 psi to 150 psi while those for metal bowls have a range up to 250 psi. They drain automatically as long as there is pressure on the air system. Additional information can be obtained by writing W. F. Stalder, A. A. Norgren Co., 3400 S. Elati St., Englewood, Colo.

LUBRICATE AT HI-TEMPERATURE

A high temperature solid film lubricant has been developed and tested for operating temperatures up to 800 degrees F with possible application up to 1000 degrees F.

This coating, made up of silicones, high temperature phenolics, and micro-fine particles of moly-disulphide and synthetic graphite, is currently operating on jet and rocket applications — on plain spherical bearings, hinge pins, shafts and journals, and electrical and pneumatic couplers. It reportedly aids in preventing galling and seizing of fasteners and other threaded members. Technical Bulletin No. 2047 gives additional details and may be obtained by writing Electrofilm, Inc., P.O. Box 106, N. Hollywood, Calif.

PROTECTIVE FLOOR COATING

Uses for SonNoMar, a fast drying liquid protective coating for concrete floors, are described in a new four page brochure available from L. Sonneborn Sons, Inc.

SonNoMar is blended of newly developed synthetic resins, and chemically inert, and highly elastic plasticizing agents. Copies of the brochure and additional information on SonNoMar may be obtained by writing the Building Products Division of L. Sonneborn Sons, Inc. Dept. BB, 404 Fourth Avenue, New York 16, N. Y.

INDUSTRIAL FILTER PAPER

A unique 24-page "work-book," liberally illustrated with photographs, charts, and diagrams, presents a clear, concise review of filtration practice, explains how paper, as a filtering media, helps solve problems in laboratory and industrial use, and is an indispensable aid in selecting one of the many grades of E-D Industrial Filter Paper for scores of applications.

Easy-to-read articles deal with such subjects as the separation of solids and fluids, industrial and laboratory filter papers, chromatography paper, folded circles for lab projects, bibulous paper, lens paper . . . even a glossary of industrial filtration terms.

(Copies of Catalog No. 357 are available by writing directly to The Eaton-Dikeman Company, Box LE — Mt. Holly Springs, Pa.)

Planned Lubrication

(Continued from p. 386)

When operating temperatures are above the range of petroleum oils, polyalkylene glycols are used as fluid lubricants.

Diesters are normally used in very low temperature service.

Fluorinated hydrocarbons are used as fluid lubricants in cases of exposure to acids and other oxidizing agents.

Chlorinated biphenyls are used if a possibility of contamination by alkalies exists.

Phosphate esters perform well in high temperature services.

High temperature compressors and other equipment which require a fire resistant fluid can be lubricated with polyalkylene glycols, chlorinated biphenyls or phosphate esters.

The use of greases by Du Pont plants is shown in Chart No. 4.

Calcium base greases are used for sleeve bearings or low speed antifriction bearings where water contamination exists. Calcium base greases adhesive additive are used for sleeve bearings, sliding surfaces, chains, cables, and open gears.

Sodium or mixed base greases normally are used for antifriction bearing service up to 250° F.

The miscellaneous greases are used as follows:

Silica base greases provide good service both for high temperature and exposure to water.

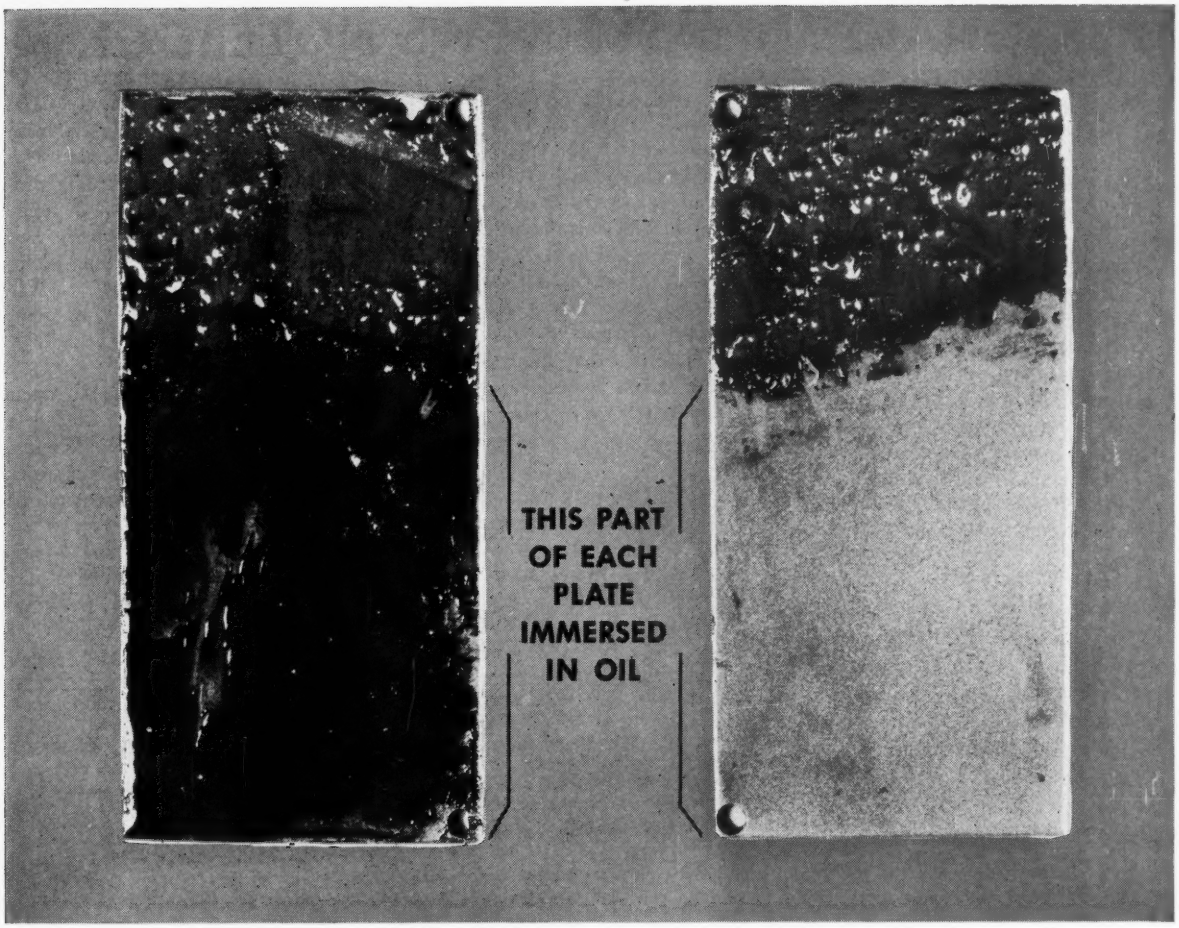
Strontium or barium base greases are used for high temperatures in exposure to water or steam.

Lithium base greases are used for low and high temperature services as well as exposure to water.

Bentone base greases are used for high temperature services. Silicone greases are used for high temperature service above 250° F.

Greases containing graphite, molybdenum disulfide, or mica provide good service in reciprocating mechanisms where an efficient lubricant film cannot be maintained.

An engineered lubrication program such as this must be pursued actively to aid in attaining machine availability, minimum shutdowns due to mechanical failure, and optimum maintenance costs in the chemical industry. Engineered lubrication can prevent emergency shutdowns which may cost thousands of dollars per hour in production losses. This emphasizes the importance of the lubrication engineer and the lubrication mechanics, the work which they do, and their contribution to the plant's maintenance effectiveness.



This sludge-coated metal plate was partially immersed in a beaker containing a *regular hydraulic oil* heated to normal operating temperature. Though the oil was agitated throughout the test, nearly all the sludge remained on the plate.

This similarly sludge-coated plate was partly immersed in a SUNVIS 700 oil, also heated to normal operating temperature. During the same period, with the same degree of oil agitation, the immersed part of the plate was rinsed clean of sludge.

Simple test shows how

SUNVIS 700 OILS CLEAN HYDRAULIC SYSTEMS...WITHOUT SHUTDOWNS

Sunvis® 700 oils clean while they work. Their cleansing action removes deposits in systems contaminated by dust, sludge, varnish, and other foreign materials.

SUNVIS 700 oils carry these contaminants in suspension for easy removal. This eliminates costly teardowns. Systems stay clean. In addition to being ideal for hydraulic systems, SUNVIS 700 oils are also suited for circulating systems and gear boxes.

If you want exceptional cleaning ability, oxidation stability, rust prevention, film strength, you need SUNVIS 700 oils. Ask your Sun representative for full details, or write to SUN OIL COMPANY, Philadelphia 3, Pa., Dept. LE-7.

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY Philadelphia 3, Pa.

IN CANADA: SUN OIL COMPANY LIMITED, TORONTO AND MONTREAL

SUNOCO®

©Sun Oil Co., 1957

PERSONALS

John C. Sprague, secretary-treasurer of Acheson Industries, Inc., New York, since 1941, was elected vice-president in charge of administration and finance at a recent board meeting in New York City, according to Howard A. Acheson, president. In addition to his new responsibilities, Mr. Sprague will continue to serve as secretary-treasurer, and will maintain his headquarters at Port Huron, Michigan.

R. M. Roach has been named New York district sales manager of Jefferson Chemical Co. A graduate of Villanova University where he received his B.S. in Chemical Engineering, Mr. Roach joined Jefferson's New York sales staff in 1953. R. J. Robinson, formerly Cleveland resident salesman is being transferred to the New York office and J. M. Luger is moving from Houston to Cleveland to take over the territory previously handled by Mr. Robinson.

Herr & Co., Inc. of Lancaster, Pa. has been appointed distributor of automotive and industrial lubricants, metal working products and foundry core binders for Swan-Finch Petrochemicals in the Lancaster-York area of Eastern Pennsylvania. Swan-Finch, of Hackensack, N. J., has also named Berkshire Color and Chemical Corp., Springfield, Mass., to serve as their distributor in Connecticut, Western Massachusetts, Vermont, and New Hampshire.

The appointment of W. W. Loveland, Jr. to a new territory in the Syracuse, N. Y. area was recently announced by J. B. Sewell, vice president in charge of sales of the Garlock Packing Co. of Palmyra, N. Y. Mr. Loveland formerly worked in Garlock's product engineering department. Prior to that, he was a sales representative for Loveland Equipment Co.

STEEL COOLANT DIRECTS SPRAY

The Spray-Cooler, a low-cost, portable cooling system for metalworking machines, directs a finely atomized spray of coolant at the exact point of cutting. The stainless steel unit is designed to prolong tool life from 50 to 500 per cent.

ASLE NEWS NOTEBOOK

A new Section was organized at Rochester, N. Y. on June 4. Officers elected include: Charles Hauser, chairman; Cort Miller, vice-chairman; Richard Knowe, secretary; and Robert Hoffman, treasurer. Meetings will be held the second Wednesday of the month. By-laws are being drafted and a charter will be applied for from the national office. Plans are being made for a lubrication course to be held at either the University of Rochester or Rochester Institute of Technology in the fall.

By-Laws Committee Organized

With the appointment of A. E. Cichelli as chairman of the by-laws committee and examination of the steps necessary to bring the by-laws up to date. the board of directors approved the preparation of new by-laws and a basic constitution. The resulting documents would deal with the basic construction and nature of the Society; with the operating procedure of the Society; and a policy statement incorporating policy and acts of the board of directors. Committee members include: C. L. Willey, L. B. Sargent, R. L. Humphreys, P. F. Chappell and A. E. Cichelli.

Board Actions

The Journal Bearing Abstracts project has been completed and a manuscript supplied for publication. Action on publication of this work was deferred until cost data could be obtained.

Revision of the by-laws according to the proposed methods of the new by-laws committee was approved by board action.

—Compiled by R. D. McCormick

ASLE Preprints Available

A limited supply of the following preprints of papers presented at the ASLE-ASME 1956 Lubrication Conference are still available at 35c each to members, 50c each to non-members. To order, indicate the number of copies desired, fill in your name and address, enclose remittance, and mail to:

ASLE, 84 E. Randolph St., Chicago 1, Ill.

_____(56LC-7) *Application of Reaction Rate Theory to the Weld Junction Aspect of Kinetic Friction Between Unlubricated Metallic Surfaces,* by F. F. Ling & E. Saible

_____(56LC-1) *Application Problems with Petroleum Lubricants in Nuclear Power Plants,* by R. F. Hausman & E. R. Booser

_____(56LC-5) *Effects of Nuclear Radiation on Lubricants,* by J. A. King & W. L. R. Rice

_____(56LC-9) *Fretting of Hardened Steel in Oil,* by J. R. McDowell

_____(56LC-6) *Fundamental Study of Synthetic Sapphire as a Bearing Material, A,* by L. F. Coffin, Jr.

_____(56LC-2) *General Radiation Damage Problems for Lubricant & Bearing-Type Materials,* by V. P. Calkins & C. G. Collins

_____(56LC-18) *Influence of Temperature on Boundary Lubrication,* by C. W. Cowley, D. J. Ultee & C. W. West

_____(56LC-13) *Investigation of "Melt Lubrication,"* by B. Sternlicht & H. Apkarian

_____(56LC-10) *PbO & Other Metal Oxides as Solid Lubricants for Temperatures to 1000° F.,* by M. B. Peterson & R. L. Johnson

_____(56LC-4) *Radiation-Resistant Greases,* by J. G. Carroll, R. O. Bolt & B. W. Hotten

_____(56LC-8) *Solid Film Lubricant—Factors Influencing Their Mechanism of Friction & Wear,* by R. E. Crump

_____(56LC-12) *Solution for the Finite Journal Bearing & Its Application to Analysis & Design — II, A,* by A. A. Raimondi & J. Boyd

_____(56LC-16) *Specific Heat at Low Temperatures and Latent Heat of Fusion of Aircraft Engine Lubricants,* by V. E. Shrock & R. E. Gott

_____(56LC-11) *Temperature Effects in Journal Bearing Lubrication,* by W. F. Hughes & J. F. Osterle

_____(56LC-17) *Thermal Conductivity & Thermal Diffusivity of Aircraft Engine Lubricants at Low Temperatures,* by V. E. Schrock & E. S. Starkman

_____(56LC-3) *Use of Rolling Contact Bearings in Low Viscosity Liquid Metal Lubricants,* by W. Markert, Jr. & K. M. Ferguson

_____(56LC-14) *Yield Stress as a Factor in the Performance of Greases,* by D. Evans, J. F. Hutton & J. B. Matthews

Name_____

Address_____

City_____ Zone_____ State_____

Lithium-Base Multi-Purpose

INLUCITE 21

STRETCHES

your grease dollar

Less inventory! Less waste! Less time-out for greasing! Fewer errors! Plus longer-lasting protection! No wonder users say grease dollars go further with INLUCITE 21, the unexcelled all-weather grease that outlasts every specialized grease it replaces. INLUCITE 21 seals out dirt, guards against wear for extra hundreds of miles between applications. Write for details.

INTERNATIONAL LUBRICATION

INTERNATIONAL LUBRICANT CORP.

NEW ORLEANS, LOUISIANA

Manufacturers of Quality Lubricants • AVIATION • INDUSTRIAL • AUTOMOTIVE • MARINE

With Research Comes Quality, With Quality Comes Leadership

Lubrication Abstracts

(Compiled by the ASLE Abstracts Sub-Committees.)

"Bearings for Marine Geared Turbines." A. D. Newman, *Int. Shipbldg. Progress, V. 3,* No. 26, 1956, 528-39. The prime requirements of bearings for marine geared turbines, reliability and efficiency, are considered. It is shown that the correct choice of length/diameter ratio and clearance ratio is essential in order to attain these requirements, and it is indicated that for the conditions which occur in most marine turbine and gear bearings, relatively short bearings with length/diameter ratio between two-thirds and one-third, and clearance ratios between one and two thousandths of an inch per inch diameter, give the best results. Bearing and shell materials are discussed. The advantages of high-tin whitemetal as bearing material are shown, and the relative merits of non-ferrous and ferrous shell materials are considered. It is concluded that the best general design is one of thin whitemetal on a steel shell; the shell may be of normal thickness or it may be of thin shell type, and the advantages of this design are considered. The requirement of utmost reliability in a marine bearing involves if possible the ability for limited operation under a condition of lubricating oil failure. The shortcomings in this respect of present bearings are mentioned, and an improved design which overcomes them is described. *(Author's Abstract)*

"A Billion Engine Hours on Aluminum Bearings" by R. S. Frank and W. J. Lux — **Paper No. 655 Soc. Automotive Engrs.* meeting January 9-13, 1956. The evolution of the adaptation of aluminum engine bearings at Caterpillar Tractor Co. is recounted. Recognized bearing properties are reviewed. The shortcomings of solid thick wall aluminum bearings are discussed, including the detrimental effect of thermal conditions on crush and clearance which limit operational temperature range. The advantage of steel backed aluminum bearings, test experiences and test procedures for bond, fatigue and frictional evaluation are described.

"Aluminum-Tin Bearing Alloys — A New Bonding Method" by P. W. Goad — *Tin and Its Uses No. 36* Summer 1956, pp. 9-10. An improved method of bonding aluminum-tin alloy to steel is described. By matching ductilities of steel and alloy strips, equal length strips and scratch brushing preparatory treatment are required and the need for aluminizing is eliminated.
"Results of Practical Trials on Aluminum-Tin Bearings" by N. Colari and L. Pagliamentale Metallic Leggeri and a titanium containing alloy developed by authors are lunga — *Tin and Its Uses No. 37* Autumn 1956, p. 5-7. The comparative wear rates of T.R.I. alloy developed by Tin Research Inst., "Lubral" developed by Institute Speri-related to composition, mechanical properties and shaft hardness from tram car axle bearing tests. *(Abstracter: A. R. Shaw)*

"Mounting Anti-Friction Bearings," by E. P. Stahl. *Plant Engineering, V. 10,* No. 5, 1956, pp. 120-21, 124, and 126. The precautions necessary to mount bearings to avoid damage are discussed. The proper methods of securing a bearing to a shaft and in the housing, and the various types of internal and external rings to retain bearings on the shaft or in the housing, are described. Several types of tools available for both mounting and dismounting of bearings to insure against damage are described in some detail. Proper packing and cleaning of bearings, to obtain full life after installation, are discussed. *(Abstracter: H. E. Kaye)*

(Ball) "Stress in Large Ring Bearings" by T. S. Williams, *Product Engineering, V. 28,* Feb. 1957, pp. 160-63. The stresses induced in the race of large ring ball bearings are considered. Owing to uneven loading induced by a nonridged inner race support, bending stresses are introduced. The formulas, graphs and the sample calculation which are presented permit the computation of the 1) maximum ball load, 2) maximum compressive contact stress and 3) the fiber stress in the race. *(Abstracter: C. M. Allen)*

"Viewer for Inspecting Balls and Rollers for Bearings," Anon., *Engineering, Vol. 182,* No. 4526, 1956, pp. 425-26. A viewer is described that provides a simple solution to the problem of examining the steel balls used in ball bearings for superficial blemishes before use. The ball is placed on the axis of a translucent tube one end of which is closed by a diaphragm having a small aperture. The tube is illuminated from the outside and when viewed through the aperture by eye or by some telescopic system the surface of the ball is uniformly illuminated and dirt dust or deposits rising from the surfaces are clearly seen. Scratches and pits below the surface can be seen clearly and with good contrast by inserting an opaque tubular screen between the ball and translucent tube. This gives dark ground illumination to the outer annulus of the ball. Light from the unscreened part of the translucent tube enters the dark field and is reflected to the viewing aperture by the edges of any pits or scratches over an area near the edge of the shadow.

"Worm-Gear Lubrication" by R. Tourret, *"Engineering, V. 180,* No. 4692, Dec. 30, 1955, pp. 888-91. The effect of oil viscosity on power losses and wear is investigated. The power loss factors of churning and friction are studied in the laboratory using motor-driven industrial units. These tests are supplemented by field trials on twin worm-gear rear axles. The laboratory results indicate that low-viscosity oils give the lower power loss at low loads, whereas at high loads, where friction losses predominate, the high-viscosity oils are more effective. The field trials indicate an increase in power loss with increase in viscosity irrespective of the load. Experiments on wear and pitting are conducted in a disc wear machine using the combination of a steel disc in contact with phosphor-bronze. Conclusions drwn are that wear and pitting are aggravated by low viscosity oils. *(Abstracter: P. A. Aseff)*

American Society of Lubrication Engineers
Founded 1945
Chicago Illinois

This certifies that

John Doe

is a

Member

of this Society organized to promote the science and practice of lubrication and for acquiring and perpetuating that knowledge necessary to the lubrication engineer.

Administrative Secretary President

NOW AVAILABLE Restyled 8-½ x 11"

ASLE Membership Certificates

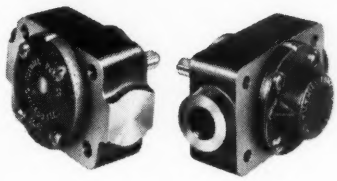
With name hand-lettered, and showing date of admission $1.50
Same as above, but suitably framed, ready for hanging $4.50

To order, indicate your preference; include your name and address, enclose remittance, and mail to:

ASLE, 84 E. Randolph St., Chicago 1, Ill.

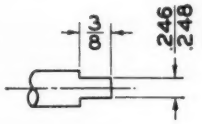
NOW! Have Reliable Lubrication at Minimum Cost

Models LF and RF
Capacities 55-170 g.p.h. at 1800 r.p.m.
Designed for flange mounting without shaft seal; with *choice* of internal or external porting. Model RF has automatic reversing feature which permits driving the pump in either direction... without changing direction of flow or port positions.

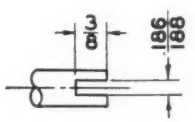


Models LFD and RFD
Capacities 60-180 g.p.h. at 1800 r.p.m.
Designed for non-directional service; for flange mounting with internal porting. Variations for external porting and/or shaft seal are shown below. Model RFD has the automatic reversing feature which permits driving the pump in either direction... without changing direction of flow or port positions.

ALTERNATE SHAFT DRIVE ENDS
For All Models



MODIFICATION "A"



MODIFICATION "B"

Tuthill "Cartridge-Type" Pumps Solve This Problem for Plant Maintenance...and Original Equipment Manufacturing

Durable—Reliable—and Available from Stock!

1. The demand for minimum cost lubrication pumps without sacrifice in performance, durability and reliability is *ideally* satisfied by the TUTHILL series of Models LF, RF, LFD and RFD *cartridge-type* pumps.

2. TUTHILL "cartridge" pumps get their reputation as cost-savers from their special design for original equipment use, their durable construction, their reliability...and the fact that they are *available from stock*. Note their compact size as shown in the photos above. Consider how all waste space has been eliminated for more adaptability. Think how they can be easily applied to your *own* requirements...in your plant...or in your equipment manufacturing plans.

3. These variables are available:

a. Pumps with...*or without*...automatic reversing performance

b. Pumps with...*or without*...a shaft seal

c. Pumps with internal...*or external*...porting

d. Pumps with *variations* of both internal and external porting

4. TUTHILL Catalog Section 108 contains line drawings showing each model in detail, shaft rotation and porting arrangements and other vital statistics to help you select the RIGHT model. Fill out the attached coupon—or write.

TUTHILL PUMP COMPANY
971 E. 95th Street, Chicago 19, Illinois

Gentlemen:

☐ Please send me Catalog Section #108
☐ Please send the complete catalog on the Tuthill line
☐ Have your representative call

NAME_____ TITLE_____

COMPANY_____

ADDRESS_____

CITY_____ ZONE____ STATE_____

Tuthill Manufactures a Complete Line of Positive Displacement Rotary Pumps in Capacities from 1 to 200 GPM, for Pressures to 600 PSI, Speeds to 3600 RPM.

TUTHILL PUMP COMPANY

971 East 95th Street, Chicago 19, Illinois
Canadian Affiliate:
Ingersoll Machine & Tool Company, Ltd., Ingersoll, Ontario, Canada

PUMPS FOR YOUR PURPOSE

Patent Abstracts

(Compiled by Ann Burchick, Aluminum Company of America.)

Rust Inhibiting Lubricating Oil Compositions, Patent No. 2,773,032 (T. L. Cantrell and J. G. Peters, assignors to Gulf Oil Corp.) A composition comprising a major amount of a mineral lubricating oil, and about 0.024 percent by weight of the composition of dimerized linoleic acid, and about 0.016 percent by weight of the composition of a salt of a primary alkyl amine containing 8 to 18 carbon atoms per molecult and 3-methyl-butyl, 2-ethylhexyl orthophosphate.

Lubricant Compositions and Treatment, Patent No. 2,773,033 (J. D. Bartleson and M. L. Christoph, assignors to The Standard Oil Co.) An oil-dispersible composition suitable for use as a lubricant additive comprising from about 0.01% to about 1% of an oil-soluble copper salt dispersed in the reaction product of a phosphorus sulfide-oxygen-containing organic compound-olefin polymer reaction product, the oxygen-containing organic compound being selected from the group consisting of those compounds containing hydroxy, carbonyl, ether and carboxy radicals, and having a boiling point of at least 225 F. with potassium hydroxide produced by reacting the last-mentioned reaction product with an amount of solid potassium hydroxide in excess of the amount required just to neutralize the reaction product within the range from over 125 equivalent up to about three equivalents per mole of the said reaction product at an elevated temperature at which the materials react for a time to complete the reaction and, separating insoluble materials from the reaction mixture to obtain an improved reaction product, and characterized by improved color, color stability and stability against liberation of hydrogen sulfide.

Treatment of Lubricants with Potassium Hydroxide and Products, Patent No. 2,773,034 (J. D. Bartleson, assignor to The Standard Oil Co.) A process for improving the color, color stability and stability against liberation of hydrogen sulfide of phosphorus sulfide-oxygen-containing organic compound-olefin polymer reaction products, said oxygen-containing organic compound being selected from the group consisting of those compounds containing hydroxy, carbonyl, ether and carboxy radicals, and having a boiling point of at least 225 F. which comprises reacting the reaction product with an amount of solid potassium hydroxide in excess of the amount required just to neutralize the reaction product within the range from over 1.25 equivalent up to about three equivalents per mole of the reaction product at an elevated temperature at which the materials react for a time to complete the reaction and separating insoluble materials from the reaction mixture to obtain an improved reaction product.

Soluble Oil Composition, Patent No. 2,773,035 (S. P. Waugh, assignor to Tidewater Oil Co.) A stable soluble oil composition comprising (in homogeneous solution, a lubricating base in major amount based upon the weight of said composition, a water soluble soap as an emulsifying agent, a coupling agent in an amount sufficient to disperse said soap in said lubricating base, and water in an amount sufficient to inhibit gelation but less than an amount sufficient to induce separation of said composition, said lubricating base comprising (a) a predominantly aromatic extract obtained by furfural extraction of a petroleum fraction and (b) a mineral oil fraction which has not been solvent extracted.

Extreme Pressure Soluble Oil Compositions, Patent No. 2,773,036 (S. P. Waugh, assignor to Tidewater Oil Co.) A stable soluble oil composition comprising, in homogeneous solution, a lubricating base in major amount based upon the weight of the composition a predominantly aromatic extract obtained by furfural extraction of a mineral oil fraction, a water-soluble soap as an emulsifying agent, an extreme pressure agent, and water in an amount sufficient to inhibit said compositio nagainst gelation but less than an amount sufficient to induce separation of said composition.

Concentrates Useful as Additives in Mineral Oil Compositions and Mineral Oil Compositions Containing Same, Patent No. 2,773,037 (J. W. Bishop, assignor to Tidewater Oil Co.) A lubricating composition comprising a mineral oil in major amount based upon the weight of said composition and a small amount, sufficient to impart anti-oxidant and anti-corrosion properties to said composition, of an oil-soluble phosphorus- and sulfur-containing reaction product of (a) an alkyl ester of an acid from the group consisting of propenoic acid and alkyl-substituted propenoic acids with (b) an acidic, phosphorus- and sulfur-containing product of reaction between an excess of a phosphorus sulfide and a predominantly aromatic extract obtained by furfural extraction of a mineral oil.

Lubricants, Patent No. 2,773,038 (W. B. Whitney and W. N. Axe, assignors to Phillips Petroleum Co.) A lubricating oil composition comprising a mineral oil having a viscosity index of at least 50 and containing an amount sufficient to impart anticorrosion properties thereto, of a product of sulfurization of a diarylalkane containing from 4 to 12 alkane carbon atoms, obtained when employing sulfur monochloride as the sulfurizing agent.

Metal Working and Liquid Coolants Therefor, Patent No. 2,780,598 (T. H. Cafcas, assignor to Standard Oil Co.) The method of minimizing the quantity of suspended metal particles in a liquid coolant which is recirculated onto the tool and work piece during a metal working operation, which method comprises employing a coolant comprising about 5 to 150 parts of water per part of an emulsifiable oil comprising between about 45 to 95% of hydrocarbon oil, between about 2 to 30% of an oil-in-water emulsifying agent, and between about 0.05 to 20% of at least one alkylene diamine compound.

Advertisers' Index

Acheson Colloids Co. 371
Alemite Div., Stewart-Warner Corp. 373
Alpha Molykote Corp., The 377
Baroid Div., National Lead Co. 413
Climax Molybdenum Co. 378
Farval Corp., The ..... (Inside Front Cover)
Hodson Corp., The ..... (Back Cover)
International Lubricant Corp. 417
Lincoln Engineering Co. 376
Sun Oil Co. 415
Trabon Engineering Corp. ..... (Inside Back Cover)
Tuthill Pump Co. 419

It's Toronto in '57

ASLE-ASME 4th Lubrication Conference

October 7-8-9 Royal York Hotel

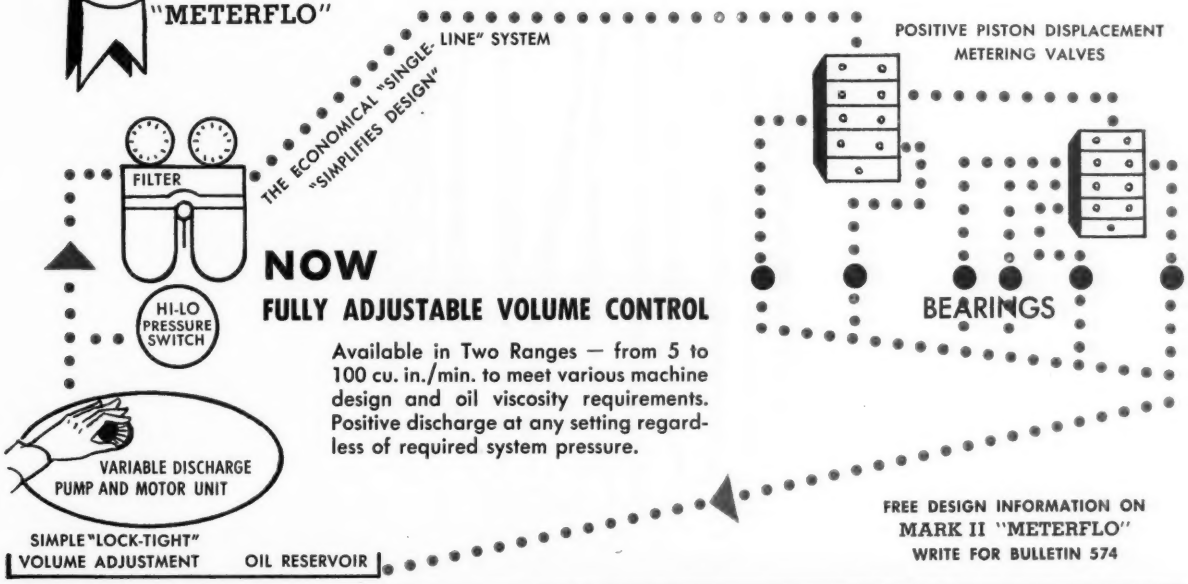
TRABON

Announces...

MARK II "METERFLO"

CIRCULATING OIL LUBRICATION SYSTEM

POSITIVE OIL FLOW TO EVERY BEARING UNDER PRESSURE



NOW

FULLY ADJUSTABLE VOLUME CONTROL

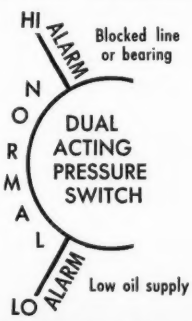
Available in Two Ranges — from 5 to 100 cu. in./min. to meet various machine design and oil viscosity requirements. Positive discharge at any setting regardless of required system pressure.

FREE DESIGN INFORMATION ON MARK II "METERFLO" WRITE FOR BULLETIN 574

PLUS CALIBRATED DUAL PRESSURE SWITCH EQUIPMENT

Compact dual-acting pressure switch now includes calibrated adjustment for simple and ready adaptation to meet all field conditions. "Pressure-dampened" switch and gauge equipment—for longest equipment life and elimination of any momentary "false" pressure signals.

Wide normal operating range assures positive metered quantity **regardless of length of line or varying bearing resistances.**



NOTE TO MACHINE DESIGNERS

- Hi-Pressure dual cartridge filter — a turn of the handle permits cartridge change without stopping system—"quad" ring seal construction for leak-proof operation.
- Wide range metering valve sizes for ultra-fine metering requirements (i.e. exposed sliding surfaces)—plus accurate control over output ratios of 20-1 and higher within the same system.
- Protection against failure of oil to reach bearings for **any** reason.
- Constant positive pressure feed regardless of change in temperature or oil viscosity.
- "Packaged" power units—complete sump, pump, and control units available in any desired combination.

For further economy, non-adjustable units also available.

TRABON ENGINEERING CORPORATION
28815 AURORA ROAD **SOLON, OHIO**

DENSOIL

DENSOIL is an extreme pressure, fibrous structure, paraffin base oil lubricant, so versatile as to be used in small gears and bearings as well as heavy-duty mill equipment where extreme conditions exist.

DENSOIL can be used advantageously for all types of enclosed geared units, both for teeth and bearings—sleeve and antifriction, from the heaviest type of industrial equipment to that used in household utilities, such as washing machines, etc.

DENSOIL Lubricant is temperature resistant. It has cushioning and shock absorbing characteristics, plus excellent adhesion and cohesion at high peripherals which prevents metal grab and consequent scoring and cutting.

DENSOIL builds up a lacquer-like, tough, oily film, high in lubricity, on bearing surfaces as used in mill equipment for Pinions, Cables, Screw Downs, Couplings, Columns, Bearings, Worm Drives and Guides.

Some plant standards specify "DENSOIL or its equivalent" . . . but there is no equivalent when it comes to this requirement.

HODSON

CASE HISTORIES

Strip Mill Screw Downs.
DENSOIL installed 1937

Tin Mill Drive and Pinions.
DENSOIL installed 1930

Worm Drives Hot Bed.
DENSOIL installed 1936

Plate Mill Tilting Table.
DENSOIL installed 1940

Copper Rod Mill Drive.
DENSOIL installed 1930

The HODSON CORPORATION

Lubrication

5301-11 WEST SIXTY SIXTH STREET

CHICAGO 38, ILLINOIS

7-L-57

PRINTED IN U.S.A.